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Part 1

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Compiled by  
Roger A. Breckenridge  
Lenwood G. Clark  
Kelli F. Willshire  
and Sherwin M. Beck  
NASA Langley Research Center  
Hampton, Virginia

Lisa D. Collier  
CTA, Inc.  
Hampton, Virginia

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## Preface

The major space goal of the National Aeronautics and Space Administration's Office of Aeronautics and Space Technology (OAST)<sup>†</sup> is to provide enabling technologies—validated at a level suitable for user-readiness—for future space missions, in order to ensure continued U.S. leadership in space. An important element in accomplishing this goal is the *In-Space Technology Experiments Program (IN-STEP)*, whose purpose it is to explore and validate, in space, advanced technologies that will improve the effectiveness and efficiency of current and future space systems.

On December 6 through 9, 1988, almost 400 researchers, technologists and managers from U.S. companies, universities and the government participated in the **OAST IN-STEP 88 Workshop**<sup>\*</sup>. The participants reviewed the current in-space technology flight experiments, identified and prioritized the technologies that are critical for future national space programs and that require verification or validation in space, and provided constructive feedback on the future plans for the *In-Space Technology Experiments Program*. The attendees actively participated in the identification and prioritization of future critical space technologies in eight major discipline theme areas. The content presented in the two parts of this NASA Conference Publication (CP), each under separate cover, reflect an overview of the workshop participants' efforts to review IN-STEP planning for the future of the program. These critical space technologies will help focus future solicitations for in-space flight experiments.

At the workshop, Dr. Harrison H. Schmitt emphasized that the nations which effectively exploit the advantages of space will lead human activities on Earth. OAST has worked closely with the aerospace community over the last few years to utilize the Space Shuttle, expendable launch vehicles, and, in the future, *Space Station Freedom*, for experimentation in space in the same way that we utilize wind tunnels to develop aeronautical technologies. This close cooperation with the user community is an important, integral part of the evolution of the *In-Space Technology Experiments Program* which was originated to provide access to space for technology research and for experimentation by the entire U.S. aerospace community.

The **PREFACE** edited for this NASA Conference Publication is based on the *IN-STEP 88 WORKSHOP* handout foreword written by Dr. Leonard Harris, Chief Engineer, Office of Aeronautics and Space Technology.

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<sup>†</sup> The Office of Aeronautics and Space Technology has since been renamed the Office of Aeronautics, Exploration and Technology (OAET). In conjunction with this change, the scope of the Human Exploration Initiative (HEI) has been broadened and renamed the Space Exploration Initiative (SEI).

<sup>\*</sup> The *IN-STEP 88 Workshop* was conducted by the Space Station Freedom Office of the Langley Research Center. Questions regarding this workshop should be directed to Dr. Roger A. Breckenridge, Deputy Manager, Space Station Freedom Office, M.S. 288, NASA Langley Research Center, Hampton, Virginia, 23665.



## Introduction

NASA's Office of Aeronautics and Space Technology (OAST) conducted a workshop December 6-9, 1988, on the In-Space Technology Experiments Program (IN-STEP) in Atlanta, Georgia. The purpose of this workshop, *IN-STEP 88*, was to identify and prioritize space technologies that are critical for future national space programs and which require validation in the space environment. A secondary objective was to review the current NASA (*In-Reach*) and industry/university (*Out-Reach*) experiments.

Finally, the aerospace community was asked to review and comment on the proposed plans for continuation of the *In-Space Technology Experiments Program* itself. In particular, this review included the proposed process for focusing the next experiment selection on specific, critical technologies as well as the process for implementing associated hardware development and integration on the Space Shuttle vehicle.

The product of the workshop was a prioritized listing of the critical space technology needs in each of eight technology disciplines. These listings were the cumulative recommendations of nearly 400 participants—including researchers, technologists and managers—from aerospace industries, universities and government organizations. The identification and prioritization of the critical space technology needs were initiated by assigning NASA chairpersons (theme leaders) to the eight major technology discipline themes requiring consideration. These themes were as follows:

- ① *Space Structures*
- ② *Space Environmental Effects*
- ③ *Power Systems and Thermal Management*
- ④ *Fluid Management and Propulsion Systems*
- ⑤ *Automation and Robotics*
- ⑥ *Sensors and Information Systems*
- ⑦ *In-Space Systems*
- ⑧ *Humans in Space*

In order to afford further structure within each theme, the chairpersons divided their themes into three theme elements each. The theme element concept allowed focused technical discussions to occur within the broad discipline themes. For each theme element, the theme leader selected government, industry and university experts to present the critical space technology needs of their respective organizations. The presentations were reviewed and discussed by the theme audiences (other members of the aerospace community), and prioritized lists of the critical technologies in need of verification and validation in space were established for each theme element. The comments and conclusions for each theme were incorporated into a summary listing of the critical space technology needs as well as associated flight experiments representing the combined inputs of the speakers, the audience, and the theme leader.

The critical space technology needs and associated space flight experiments identified by the participants provide an important part of the strategic planning process for space technology development and provide the basis for the next solicitation for space technology flight experiments. The results of the workshop will be presented in the *IN-STEP Selection Advisory Committee* in early 1989. This committee will review the critical technology needs, the funding available for the program, and the space flight opportunities available to determine the specific technologies for which space flight experiments will be requested in the next solicitation.

## Conference Publication Content Description, Parts 1 and 2

The proceedings handbooks were organized as three presentation categories in four volumes: (1) Overview (Executive Summary volume), (2) In-Reach/Out-Reach experiments and the experiment integration process (Volume I), and (3) critical technology presentations (Volumes II and III). For presentation in this NASA Conference Publication (CP), a two-part set (under separate covers), the Executive Summary and Volume I are combined in Part 1 and Volumes II and III are combined in Part 2.

### Part 1

**Keynote Address** — Part 1 of the IN-STEP 88 CP set opens with the keynote address presented at the workshop banquet by Dr. Harrison Schmitt, a former U.S. Senator and Apollo astronaut, on the 16th anniversary of his lunar launch (Apollo 17). In his presentation, Dr. Schmitt outlined his vision for the future of the U.S. space program by describing a *Millennium Project* which would combine space ventures to the Moon, to Mars, and to planet Earth.

**Executive Summary** — The *Executive Summary* (first half of Part 1) contains the welcome and workshop instructions, strategic planning for the in-space technology experiments, an overview of the space technology experiments being conducted in OAST as well as the solicitation process for IN-STEP, the proposed accommodation process for *Space Station Freedom*, and the critical-technology-needs summaries for each theme. These summaries are presented in a standardized format version of the lists prepared in "real-time" at the workshop.

The *Welcome and Workshop Instructions* describes the purpose, the process, and the product intended for the workshop. The *Space Strategic Planning* process describes the OAST space research and technology base programs which generate new technology concepts in the major discipline areas, the new focused programs of the Civil Space Technology Initiative (CSTI) as well as the Pathfinder, and provides funding for the industry, university and NASA space technology experiments. Overview charts of current OAST sponsored space flight experiments and specific information regarding the IN-STEP solicitation process are provided to establish an understanding of space technologies currently validated and the proposed approach for initiating new experiments.

Brief overviews of the objectives, technology needs/backgrounds, descriptions, and development schedules for current industry, university and NASA space flight technology experiments are presented in the second half of Part 1 (Volume I of the original workshop handbook set). This was a very important part of the workshop, providing an opportunity for the aerospace community to interact with experimenters and provide feedback on the flight experiments. An overview of the user/payload integration and accommodation process being established for use on *Space Station Freedom* is included in the content of Part 1 **Experiment Descriptions** to promote better understanding within the space experiment community, and presentations describing the experiment integration process are presented at the end of Part 1.

### Part 2

**Critical Technologies** — Part 2 of the IN-STEP 88 CP set combines the contents of Volumes II and III of the original handbook set. This book contains a theme introduction by each chairperson, critical technology presentations for each of the theme's three elements of technical focus, and summary listings of critical space technology needs for each theme. The introduction for each theme includes the chairperson's overview and instructions for the participants. The critical technology presentations, along with summaries listing the critical space technology needs and associated flight experiments, are presented as previously described.



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<sup>†</sup> Dr. Ambrus' presentation for the IN-STEP 88 Workshop was given by Dr. Harris.



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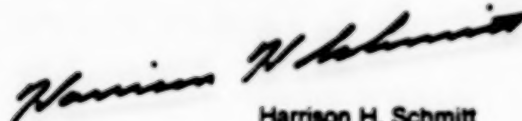


Keynote Address

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**Mission to Earth, Moon, and Mars**

Dr. Harrison H. Schmitt  
Scientist, Administrator, Educator, Consultant on Space Initiatives  
Former U.S. Senator and Lunar Module Pilot for Apollo 17



Harrison H. Schmitt

**BIOGRAPHICAL SKETCH**

P.O. Box 14338  
Albuquerque, NM 87191-4338  
(505) 823-2616

Harrison "Jack" Schmitt has the varied experience of a geologist, scientist, astronaut, pilot, administrator, educator, writer, and United States Senator.

He trained as a geologist and scientist at the California Institute of Technology, as a Fulbright Scholar at the University of Oslo, and at Harvard University, receiving his Ph.D. in geology from Harvard in 1964 based on earlier field studies conducted in Norway.

He was selected for the Apollo Scientist-Astronaut program in 1965 and served as the Lunar Module Pilot for Apollo 17--the last Apollo mission to the Moon.

Schmitt's studies of the Valley of Taurus-Littrow on the Moon in 1972, as well as his earlier scientific work, made Schmitt one of the leading experts on the history of the terrestrial planets. As the only scientist to go to the Moon, he was also the last of twelve men to step on the Moon.

After organizing and directing the activities of the Scientist-Astronaut Office and of the Energy Program Office for NASA in 1973-1975, Schmitt fulfilled a long-standing commitment by entering politics. He was elected to the U.S. Senate from his home state of New Mexico in 1976.

In his last two years in the Senate, Senator Schmitt was Chairman of the Senate Commerce Committee's Subcommittee on Science, Technology, and Space and of the Senate Appropriations Committee's Subcommittee on Labor, Health and Human Services, and Education. He currently serves as a member of the Army Science Board and as consultant to the National Strategic Materials and Minerals Program Advisory Committee.

Harrison Schmitt is consulting, speaking, and writing on a wide range of business, foundation, and government initiatives. His principle activities are in the fields of technology, space, defense, biomedicine, geology, and policy issues of the future. He brings to the consideration of complex public and corporate concerns a unique breadth of experience ranging from the scientific to the practical and from the administrative to the political.

<b>INSTEP-88 Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>	<b>Executive Summary</b>
<b>Keynote Address</b>	<b>Keynote Address</b>
<p style="text-align: center;"><b><i>Mission to Earth, Moon, and Mars</i></b></p> <p style="text-align: center;">Dr. Harrison H. Schmitt  Scientist, Administrator, Educator, Consultant on Space Initiatives  Former U.S. Senator and Lunar Module Pilot for Apollo 17</p> <hr/> <p style="text-align: center;">MISSION TO EARTH, MOON, AND MARS</p> <p style="text-align: center;">Harrison H. Schmitt</p> <p>Let us jump ahead to late January, 1990, and try to anticipate what should be the concluding paragraphs of the President's State of the Union Address to the Congress.</p> <p>"Now, my fellow Americans, as your representatives assembled in these historic chambers know so well, there has been a rising tide of domestic and international political pressure in support of initiatives for the future. You have made us all increasingly aware that both vulnerabilities and opportunities in America's future and in the future of humankind require our urgent attention. The unfair inequities of the present still do and will always demand our concern and our compassion, however, many issues essential to the future well-being of our children and our country have been too long neglected.</p> <p>"Therefore, over the next 60 days, I will send to the Congress a number of proposals that address long term structural changes in our approaches to education, the environment, retirement and health security, basic research, and other critical areas.</p> <p>"Tonight, because of the central roles played by environment and space in the future of our children, I am calling on the Congress to provide the long term commitments necessary to undertake a specific project focused on the turn of the Third Millennium. Although this rare milestone is only 10 years away, the challenge has grown to for a Millennium Project that will match the times and the opportunities.</p> <p>"Our Millennium Project, in which we invite the family of nations to join, will be the establishment of a permanent human outpost on Mars by 2010 and, by so doing, provide the technology base necessary to preserve the Earth's global environment.</p> <p>"The creation of a permanent outpost on Mars will have as its primary purposes the eventual settlement of the planet Mars by free human beings and the provision of abundant and environmentally benign electrical power on Earth. The bridge between these two essential achievements is the development of helium-3 fusion</p>	

<b>INSTEP-88 Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>	<b>Executive Summary</b>
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<p style="text-align: center;"><b>Mission to Earth, Moon, and Mars</b></p> <p style="text-align: center;"><b>Dr. Harrison H. Schmitt</b>  <b>Scientist, Administrator, Educator, Consultant on Space Initiatives</b>  <b>Former U.S. Senator and Lunar Module Pilot for Apollo 17</b></p> <p>power plants on Earth fueled by the helium resources of the moon. This bridge of energy also provides, as by-products from the energy resources of the moon, the oxygen, hydrogen, and other consumable materials critical to sustaining the early settlers of Mars.</p> <p>"Thus, our Millennium Project combines space ventures to the Earth, moon, and Mars into a single great human mission -- a mission to save the atmosphere, waters, and rainforests of Earth, a mission to settle the moon and utilize its resources for the benefit of all, and a mission to establish human civilization and freedom permanently on Mars.</p> <p>"A draft treaty for international participation in The Millennium Project is being circulated among the nations of Earth. This treaty, tentatively called the INTERMARS Charter, proposes a participant based relationship between nations, users, and investors, modeled after the successful International Telecommunications Satellite or INTELSAT Agreements. It is the intention of the United States Government that an international conference to finalize the INTERMARS Charter will be convened by interested nations before the end of the year.</p> <p>"Ladies and gentlemen and my fellow Americans, our commitment to the success of The Millennium Project must be unequivocal. It must include an equally unequivocal commitment to carry the sacred institutions of freedom with us as humankind expands into its larger home among the planets and the stars."</p> <p>The recent return of American astronauts to space, as satisfying as it must be to those of you responsible, constitutes but a very small step in the repair of what can only be called a space policy disaster.</p> <p>Challenger and the tragedy of its loss did not cause this policy disaster nor was it caused by the dedicated people of NASA and its contractors whatever errors in judgment may have been made. The now so obvious loss of momentum in the United States space program has been the result of a loss of will on the part of national leadership spanning almost two decades.</p> <p>Humankind's first explorations of the moon and of space near the Earth between 1968 and 1972 were also the species first clear steps of evolution into the solar system and eventually into the galaxy. As the Pueblo Indians tell the lesson of their ancestors, "We walk on the Earth, but we live in the sky."</p>	



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*Mission to Earth, Moon, and Mars*

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Early explorers of the sky not only took their eyes and minds into space and became the eyes and minds of billions of other explorers on the starship Earth, but they began the long process of transplanting civilization into space. This fundamental change in the course of history has occurred as humans also have gained new insight into themselves and their first planetary home.

Limitless seas in space exist not only as new frontiers but as new challenges for humankind. The nations on Earth which effectively utilize technology to exploit the economic and military advantages of the new ocean of space will dominate human activities on this planet well into the next century, if not indefinitely. Those nations also will provide the irreversible templates for the social and political evolution of civilization beyond the next century far into the Third Millennium.

The first response to this challenge in space by the United States under President John F. Kennedy's leadership appeared to recognize the historic proportions of the contest. The leading involvement of the United States in space initially insured that the traditions of free institutions would be represented. As a consequence, at the high point of the Apollo Program, the United States verged on the establishment of bases on the moon, research stations in earth orbit, and the statement of a realistic goal of a foothold on Mars by the end of the Century. In the motto of the last Apollo mission to the moon in December 1972, the conclusion of the Apollo Program truly could have been "The End of the Beginning."

The opportunity given to humankind by the Apollo Program and its generation passed by. Consequently, the responsibility to re-ignite Kennedy's torch for space falls to others. The emotional energy to light that torch could be supplied to generations now alive by the vision of the human settlement of Mars and by the necessity of providing vast amounts of environmentally compatible energy for the billions of humans left at home.

The return of Americans and their partners to space must be viewed in the context of the free world's over all perception of the future of humankind. In the United States, unfortunately, little political thought normally is given to that future or to our role with in it. However, in space, we have little choice. The United States will be the free world's principal agent and advocate in space, because there are no other likely alternatives.

One body of opinion in the U.S. today would argue that there is no hurry. "Space will always be there, and meanwhile we have more pressing near term interests here on Earth. What is interesting to do scientifically can be done with robots at



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much lower cost." Unfortunately for those who hold this opinion, times are changing rapidly, and there is history being made without us. The challenge in space can no longer be viewed as merely a scientific challenge as valuable as the science to be done will be. The challenge now is to both lead the human settlement of space and the environmental preservation of our home planet.

Why the hurry? Why stretch human technological and psychological reach to the limit? First and foremost, the answers are in the minds of young people who will carry us into the Third Millennium. The answers are in the generations now in school, now playing around our homes, now driving us to distraction as they struggle toward adulthood. They will settle the moon and then Mars. They will do this simply because they want to do this. They want to "be there". "Being there" remains the essential human ingredient in life's meaningful experiences.

The desire to "be there" will drive our young people away from the established paths of history on a now too confining Earth. It will take them and their progeny to an infinity of opportunity among the planets and the stars. Video pictures and data streams from robots on Mars, no matter how good or how complete, will never be enough for the parents of the first Martians. Somewhere, those parents are alive today. Whether they now play on the steppes of Russia, on the river banks of China, or on the mountains, plains, and shores of America, or on a combination of all three, constitutes the most critical question of national will we face today.

Thus, an answer to "why the hurry" also lies in the clear determination of the Soviet Union to establish its sovereignty in deep space and on Mars before the forces of freedom do so. The permanently occupied MIR space station, very long duration earth orbital flights by the cosmonauts, heavy lift launch vehicle testing, and their public emphasis of Mars exploration, leading to human visits early in the 21st Century, all tell us what the Soviets expect to do. In spite of all the real and perceived difficulties faced by the Soviet Union in the future, there is now reason to count on their failure in space.

Perhaps the most important answer from the perspective of the physical welfare of the human species lies in the absolute moral and political requirement to provide the ever expanding population of Earth with an ever improving quality of life. We do not currently have the technical means to do this. We do not know how we are going to provide the ten billion human beings expected before the end of the 21st Century with both the hope and the reality that they will have defeated the four horsemen of worldwide disaster: poverty, hunger, disease, and ignorance. The essential ingredient for victory in this very human battle is environmentally

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compatible energy. Fossil fuels, the rainforests, and conventional nuclear power cannot provide the answer without either unexceptable political conflict or potentially devastating consequences to the biosphere of the Earth.

Fusion power plants fueled by helium-3 from the moon (Wittenberg, 1986) could supply the electrical energy human civilization will require to maintain and expand human quality of life as we enter the Third Millennium. Inherently safe and potentially low cost fusion reactors fueled by lunar helium-3 also could become the basis for producing large quantities of continuously available electrical power in space, for highly efficient space propulsion to and from Mars, and for life giving by-products that insure the self sufficiency of settlements on the moon and Mars (Kulcinski, 1987).

Furthermore, establishment of a permanent settlement on the moon, based on the production of helium-3 for use as an energy source on Earth fully supports the desire to live on Mars as soon as possible.

First of all, most of the technology needed for the creation of a permanent lunar settlement with a resources production economy will support the technological requirements for establishing a Martian settlement. The compatible technologies include heavy lift launch vehicles, long duration surface habitats and mobility systems, resource production facilities, regular and routine capability to work in a hostile and dusty environment, and new concepts in equipment automation, reliability, longevity, and maintainability.

Second, the direct and indirect by-products of helium-3 production from the lunar surface materials will provide a ready source of necessary consumables for Martian inhabitants prior to and possibly even after the creation of their own consumables industry. These lunar produced consumables include hydrogen, oxygen, nitrogen, carbon, and food.

A preliminary estimate of the energy equivalent value of helium-3 today is about two billion dollars per metric tonne if matched against the cost of coal currently used to produce electricity in the United States. This is roughly equivalent to \$14 per barrel oil at today's prices. Two billion dollars worth of fuel currently supplies the electrical power needs of the United States for about two weeks or of a city of 10 million for about one year. The foregoing estimates of value do not take into account the additional value of by-products from lunar helium-3 production or the spin-off value of related technologies.

The principle advantages of the helium-3 fusion power cycle on Earth over other nuclear cycles include:

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1. About 99 percent of the energy released is in charged particles (protons) that induce no radioactivity in other materials.
2. High efficiency (70-80 percent) in energy conversion due to the potential for direct conversion of protons to electricity.
3. Less waste heat to be rejected due to high efficiency.
4. The energy of each of the few neutrons released (1 percent of total energy) is only one-fourth that released in other fusion cycles and such neutrons create no significant quantities of long lived radioactive waste.
5. A potentially shorter time to licensed commercialization than for other fusion cycles due to the absence of significant radioactivity and waste heat.

Estimates of the ultimate steady-state costs of delivering helium-3 to deuterium/helium-3 power plants on Earth run about one billion dollars per metric tonne. If such cost prove to be correct, such power plants will provide much lower cost electricity as well as much less environmental impact than other competing power sources proposed for the 21st Century.

The only major technical disadvantage of the deuterium/helium-3 fusion cycle is that the ignition temperature and confinement pressure required to initiate fusion is about four times higher than for the competing deuterium/tritium cycle. This disadvantage appears to be becoming less and less significant as new fusion confinement technologies are developed. In fact, a recent test in Great Britain produced a record 60 kilowatts of fusion energy using deuterium and helium-3 (G.L. Kulcinski, personal communication).

Sufficient helium-3 is available on Earth (largely from tritium decay and natural gas) for development and prototype testing of deuterium/helium-3 power plants. Therefore, the primary issues that must be addressed to determine the feasibility of a commercial helium-3 industry are, first, the technical and economic feasibility of deuterium/helium-3 commercial reactors and, second, the technical and economic feasibility of providing lunar helium-3 to fuel such reactors.

Historically, major extensions of the benefits of civilization have built on extensions of the existing



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foundation of scientific and technical understanding. The creation of the pyramids, the aqueducts and roads of the Roman Empire, the Gothic Cathedrals, the industrial revolution, the airplane, the construction of the Panama Canal, the green revolution in agriculture, and controlled nuclear energy have followed this pattern. No less than these examples, Apollo exploration of the moon and the technological revolution brought about by space flight matched the experience and technology of the past with the imagination and research of the moment.

New explorations at the frontiers of space, that is, in places and for times that are significantly beyond the technical capabilities of Apollo, Skylab, the Space Shuttle, and the space station also will require new technologies to augment those necessary to live and work in near Earth space. New and more rapid interplanetary rockets and new concepts of life support, mobility, and transportation will obviously be necessary. Foresight will be required to invest a reasonable proportion of available resources in these essential new technologies.

In the political climate of the last two decades, however, it is probably appropriate to ask, "do the discussions of future large scale space activities have any actual relevance in the United States today?" This question is particularly topical in view of the very limited commitment to major space activities put forth in the recent congressional and presidential campaigns.

Positive indications of the relevance of discussions related to space are found in the interest and motivation of a core of a few tens of thousands of technical, scientific, and philosophical advocates, in the extraordinary qualitative support of the American people for the space program, and in the historical imperative space imposes on free men and women.

Polls and surveys indicate that 75% or more of the American people support a strong space program. 75% support for anything is almost beyond rational explanation. Space has the potential to excite and motivate almost anyone.

Even if this overwhelming qualitative support did not exist, the question would still have to be asked, "if the Americans do not insure that free institutions are established elsewhere in the solar system, who else will guarantee that they will be?" Further, "if the Americans do not insure the ultimate survival of the Earth's biosphere, who else will guarantee that survival?" These fundamental points have been missed in almost all political and technical debates on the future course of the U.S. space effort.

Unfortunately, the indications of a lack of current political relevance of any discussion about advanced space



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Scientist, Administrator, Educator, Consultant on Space Initiatives  
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technology are staggering as any regular reader of Aviation Week and the Wall Street Journal will soon discover.

First, few candidates for political office feel any need to address civilian space activities as a significant philosophical, political, or environmental issue. Nor do they feel the need to address any of the broad spectrum of other critical issues of the future. The short term vested interests dominate their view because that is where elections and re-elections are won or lost.

Second, in spite of tentative commitments to it, the space station may lose its battle for domestic and international legitimacy -- on the one hand, the Administration has failed to make an unequivocal domestic political case for a U.S. managed space infrastructure and, on the other hand, the Soviets have a ten year lead in space station capability with the permanently occupied MIR station already in orbit.

Third, a U.S. heavy lift launch capability, critical to so many aspects of the future in space, does not exist. Again, the Soviets have a ten year lead in such capability which now includes an apparently competitive space shuttle.

Fourth, no significant resources are being allocated to recasting the free world's space agenda toward the settlement of Mars while, once again, the Soviets have at least a ten year lead in planning and developing such a capability.

Fifth, many national leaders are committed to severe limitation on the development of strategic defenses while the Soviets appear to be nearing a strategic defense breakout in ground based systems.

Sixth, our national leaders as well as the armed services have been unable to recognize the values of integrated manned and automated space based systems in tactical and strategic defense doctrines while the Soviets continue to develop and exercise their decades old commitment to an integrated Earth and space military doctrine. As the CINCSPACE, General Piotrowski, has said recently, the Soviets can rapidly and effectively exercise control of space -- the U.S. cannot do so.

Seventh, no workable policy exists that would insure that the U.S. and its allies would have an assured supply of critical energy and materials and the related industrial base necessary to sustain either long term space activities or near term defense and economic activities (Nott Committee, 1988). Indeed, no national leader appears to recognize that this is even an issue, witness the limited factual basis for proposals related to southern Africa.

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Even this list does not tell the whole terribly sad story as many of you know better than I.

How did we fall so far from the dizzy heights of Apollo? 1970 was the fateful year history must mark as the year the nation's political leadership began to let our space momentum and maybe our national destiny slip away.

Ironically, the people of Apollo, in spite of their spectacular success in meeting President John Kennedy's challenge, "to put men on the moon and return them safely to Earth," had lost the media and political support necessary to build on their accomplishments.

Once Apollo missions began to be canceled and the industrial base to utilize the Apollo technology base started to be dismantled, the opportunity to lead humankind into space began to slip away. Even the reluctant decision by the Nixon Administration to build the Space Shuttle, and the equally reluctant decision by the Carter Administration to continue, were made out of context relative to any grand design for our future in space. The underfunding of the Shuttle development program, by at least a factor of three less than prudent estimates of the time, was the direct consequence of this hesitant and uncomprehending political environment. The seeds of the Challenger accident were sown by these events. Their tragic harvest sixteen years later is a stark indictment of all who let this drift in space policy begin and continue.

America, like Ebenezer Scrooge, still has time to change this specter of history yet to come. So, rather than conclude on the preceeding pessimistic recital of history and current reality, let me return to the areas of technological challenge before America and the possibilities for progress before the humankind by referring back to the hypothetical State of the Union Address.

"Our Millennium Project combines space ventures to the Earth, moon, and Mars into a single great human mission -- a mission to save the atmosphere, waters, and rainforests of Earth, a mission to settle the moon and utilize its resources for the benefit of all, and a mission to establish human civilization and freedom permanently on Mars.

"Our commitment to the success of The Millennium Project must be unequivocal. It must include an equally unequivocal commitment to carry the sacred institutions of freedom with us as humankind expands into its larger home among the planets and the stars."

<b>MASTER Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Space In Executive Summary &amp; Experiment Descriptions</b>		<b>Executive Summary</b>
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<b>Mission to Earth, Moon, and Mars</b>  <b>Dr. Harrison H. Schmitt</b> <b>Scientist, Administrator, Educator, Consultant on Space Initiatives</b> <b>Former U.S. Senator and Lunar Module Pilot for Apollo 17</b>		
<p style="text-align: center;"><b>References</b></p> <p>Kulcinski, G.L., and Schmitt, H.H. (1987) The moon: An abundant source of clean and safe fusion fuel for the 21st Century, 11th Intl. Sci. Forum on Fueling the 21st Century, Oct. 1987, Moscow, USSR (UNFDM-730).</p> <p>Hott Committee (1988) National Strategic Materials and Minerals Program Advisory Committee Report, Nov. 1988, Dept. Interior.</p> <p>Wittenberg, L.J., Santarius, J.F., and Kulcinski, G.L. (1986) Lunar source of He-3 for commercial fusion power, Fusion Technology, v. 10, p. 167 (UNFDM-709).</p> <p>See also:</p> <p>Schmitt, H.H (1985) A Millennium Project -- Mars 2000, in W.W. Mendell, ed., Lunar Bases and Space Activities of the 21st Century, LPI, Houston, p. 787-794.</p> <p>Schmitt, H.H (1986) INTERNARS: User-controlled international management system for missions to Mars, in Manned Mars Missions Working Group Papers, NASA M002, v. 2, June 1986.</p>		

### Workshop Purpose & Agenda

Dr. Leonard Harris  
Chief Engineer  
Office of Aeronautics & Space Technology, NASA HQ

## IN-STEP 88

### • PURPOSE

- IDENTIFY & PRIORITIZE IN-SPACE TECHNOLOGIES WHICH:
  - ARE CRITICAL FOR FUTURE NATIONAL SPACE PROGRAMS
  - REQUIRE DEVELOPMENT & IN-SPACE VALIDATION
- REVIEW CURRENT NASA (IN-REACH) & INDUSTRY/UNIVERSITY (OUT-REACH) EXPERIMENTS WITH THE AEROSPACE COMMUNITY
- OBTAIN AEROSPACE COMMUNITY COMMENTS & SUGGESTIONS ON OAST IN-STEP PLANS

### • PRODUCT

- AEROSPACE COMMUNITY RECOMMENDED PRIORITY LISTING OF CRITICAL SPACE TECHNOLOGY NEEDS & ASSOCIATED SPACE FLIGHT EXPERIMENTS

## TECHNOLOGY THEMES

### IN-STEP 85 WORKSHOP

SPACE STRUCTURES  
SPACE ENVIRONMENT EFFECTS  
ENERGY SYSTEMS & THERMAL MANAGEMENT  
FLUID MANAGEMENT  
AUTOMATION & ROBOTICS  
INFORMATION SYSTEMS  
IN-SPACE OPERATIONS

### IN-STEP 88 WORKSHOP

SPACE STRUCTURES  
SPACE ENVIRONMENT EFFECTS  
POWER SYSTEMS & THERMAL MGMT.  
FLUID MANAGEMENT & PROPULSION SYSTEMS  
AUTOMATION & ROBOTICS  
SENSORS & INFORMATION SYSTEMS  
IN-SPACE SYSTEMS  
HUMANS-IN-SPACE



**Workshop Purpose & Agenda**

**Dr. Leonard Harris**  
**Chief Engineer**  
**Office of Aeronautics & Space Technology, NASA HQ**

## **RESULTS OF THE WORKSHOP**

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- **STRENGTHEN COMMUNICATION WITH THE AEROSPACE COMMUNITY ON THE IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM**
- **IDENTIFY CRITICAL IN-SPACE TECHNOLOGY NEEDS FOR FUTURE RESEARCH & DEVELOPMENT**
- **PRIORITIZE SPACE TECHNOLOGY NEEDS & ASSOCIATION IN-SPACE TECHNOLOGY EXPERIMENTS**

## **WORKSHOP AGENDA**

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- Dec 6**                    -   **PROGRAM OVERVIEW**  
(Tuesday Morning)
- Dec 6**                    -   **REVIEW OF CURRENT IN-REACH & OUT-REACH EXPERIMENTS**  
(Tuesday Afternoon)
- Dec 7**                    -   **THEME REVIEWS & DISCUSSIONS**  
(Wednesday & Thursday Morning)
- Dec 8**                    -   **EXPERIMENT INTEGRATION PROCESS**  
(Thursday Afternoon)
- Dec 9**                    -   **CRITICAL TECHNOLOGY REQUIREMENTS**  
(Friday Morning)

*In-Space Technology Experiments in NASA's Strategic Planning*

Dr. Judith H. Ambrus  
Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA HQ

**SPACE R&T PROGRAM**

~~OAST~~

~~IN-STEP-99~~

**GOAL**

- **RECOGNIZED LEADERSHIP IN SPACE R&T TO ENABLE AND ENHANCE FUTURE CIVIL SPACE MISSIONS**

**AND**

- **PROVIDE A SOLID BASE OF CAPABILITIES AND TALENT TO SERVE ALL NATIONAL SPACE SECTORS**

**STRATEGY**

~~OAST~~

~~IN-STEP-99~~

- **ENSURE INNOVATIVE R&T BASE**

**LONG RANGE PLAN**

- **PURSUE NEW DIRECTIONS THROUGH ROLLOVER**
- **NURTURE NEW FOCUSED PROGRAMS**
  - **ULTRA-RELIABLE SYSTEMS**
  - **TECHNOLOGIES FOR MISSION TO PLANT EARTH**
- **ADVOCATE BUDGET GROWTH**

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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA Hqs

**R&T BASE CHARACTERISTICS**

~~DAST~~

~~IN-SPACE~~

- LABORATORY RESEARCH
- GENERIC, FUNDAMENTAL
- ANALYTICAL MODELING
- ENGINEERING DATA BASE
- HIGH RISK, HIGH PAYOFF
- TECHNOLOGY OPPORTUNITIES

**RESEARCH CENTERS**

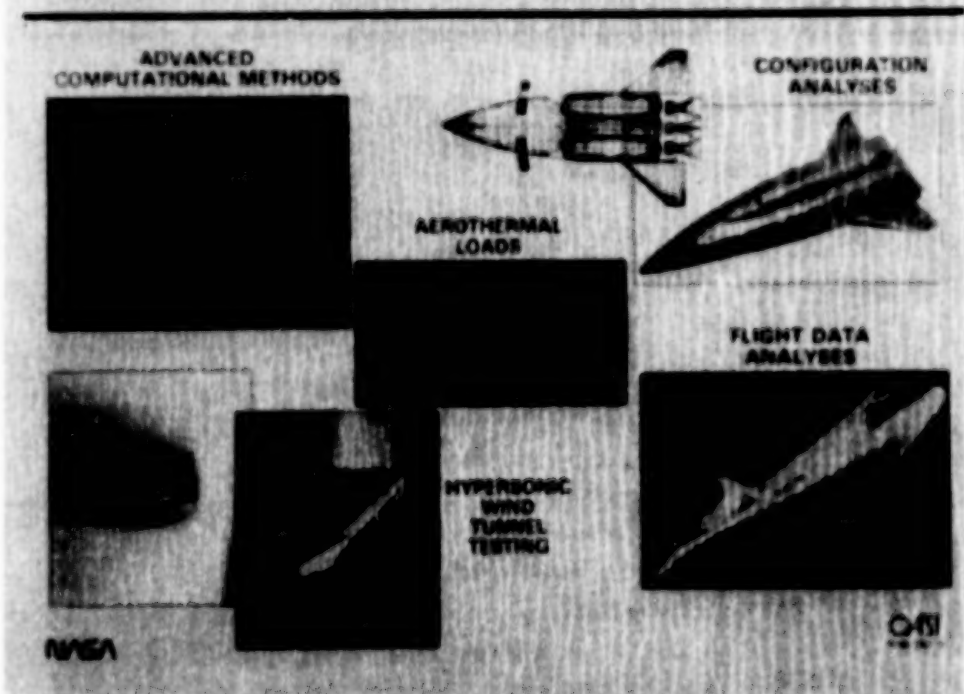


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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA Hqs



## **AEROTHERMODYNAMICS**





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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA HQ

**SPACE ENERGY CONVERSION**



NASA

OST

**PROPULSION**

LOX/HYDROGEN

AIRBREATHING

LOX/HYDROCARBON

REUSABLE EARTH-TO-ORBIT

ELECTRIC  
PROPULSION

OTV  
PROPULSION

NASA

OST

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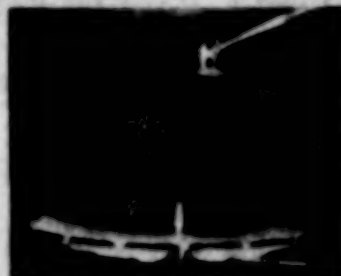
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Assistant Director for Space  
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**MATERIALS AND STRUCTURES**

**STRUCTURAL CONCEPTS**



**AEROTHERMAL STRUCTURES**



NASA

**DYNAMICS OF FLEXIBLE  
STRUCTURES**

**SPACE  
DURABLE  
MATERIALS**



ON

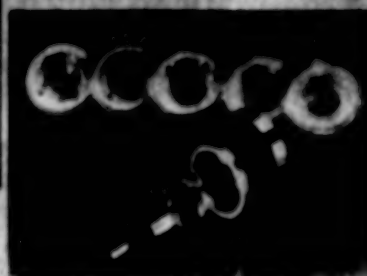
**SPACE DATA AND COMMUNICATIONS**

**LASER COMMUNICATIONS**

**LARGE APERTURE  
ANTENNA**



NASA



**ADVANCED  
TRAVELING WAVE TUBE**

**ON-BOARD  
PROCESSING  
COMPONENTS**



ON

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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA Hqs

**INFORMATION SCIENCES**

**REMOTE SENSING**



NASA

**COMPUTER SCIENCES**



EXPERT SYSTEMS

OAST

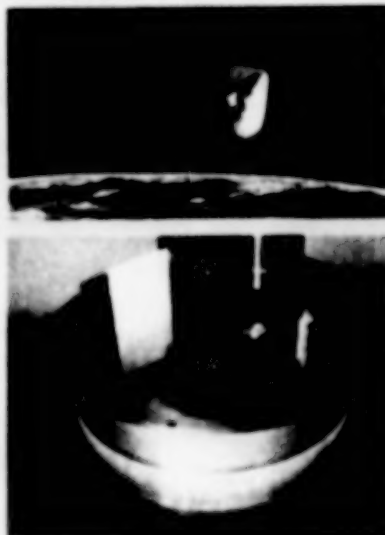
**CONTROLS AND GUIDANCE**

**BEAM DYNAMICS**



NASA

**ADAPTIVE CONTROL (AFI)**



LASER GUIDANCE  
RESEARCH

**SPACECRAFT CONTROL  
LABORATORY  
EXPERIMENT**



OAST

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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA HQ

**HUMAN FACTORS**

SPACE  
SUIT



EVA AIDS



CREW  
STATION  
DESIGN



NASA

DISPLAY  
MODELING

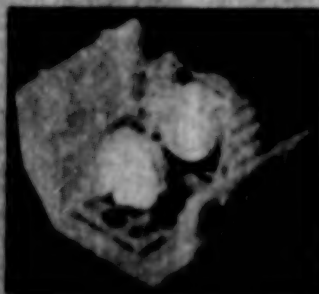


OST

**SPACE FLIGHT SYSTEMS R&T**



ORBITER EXPERIMENTS  
(OEK)



CRYSTALLINE FLUID  
MANAGEMENT

NASA

SPACE



SOLAR  
ELECTRIC  
PROPULSION  
(SEP)

SPACE  
FLIGHT  
EXPERIMENTS

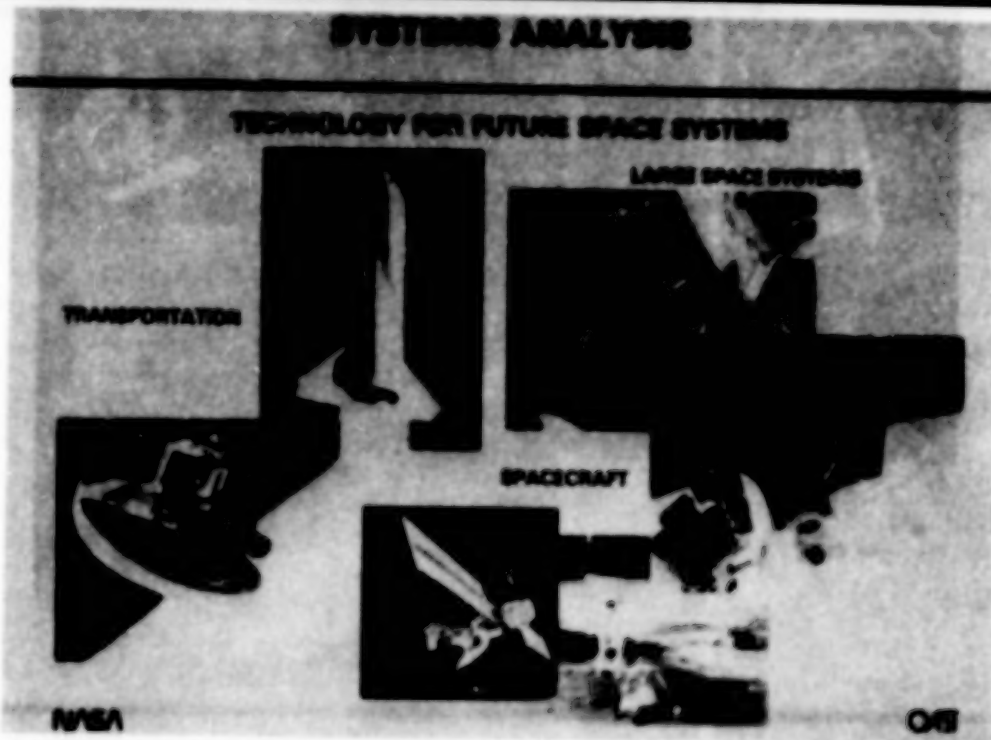


OST



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Dr. Judith H. Ambrose  
Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA HQ



**SPACE RESEARCH & TECHNOLOGY BASE**

~~OAST~~

~~IN OAST-88~~

**CANDIDATE EXAMPLES FOR FUTURE EMPHASIS**

- SOFTWARE ENGINEERING
- HIGH TEMPERATURE SUPERCONDUCTORS
- OPTICS
- COMPUTATIONAL CONTROLS
- NDE/NDI
- TECHNOLOGY FOR SELF REPAIR
- BASIC RESEARCH IN "INHERENT RELIABILITY"
- MICROSAT TECHNOLOGY
- WORLD MODELING DATA SYSTEMS

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**Dr. Judith H. Antares**  
**Assistant Director for Space**  
**Office of Aeronautics & Space Technology, NASA HQ**



**BACKGROUND**

- **THE FIRST STEP IN REVITALIZING THE NATION'S CIVIL TECHNOLOGY BASE**
- **WILL FILL IN GAPS IN MANY TECHNOLOGY AREAS**
- **FOCUSED TECHNOLOGY EFFORT, WILL RESULT IN DEMONSTRATED / VALIDATED TECHNOLOGIES**

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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA HQ

**MISSION NEEDS**

- **TRANSPORTATION TO LOW EARTH ORBIT**
  - PROPULSION
  - AEROBRAKING
- **OPERATIONS IN LOW EARTH ORBIT**
  - AUTONOMOUS SYSTEMS
  - TELEROBOTICS
  - POWER
- **SCIENCE**
  - STRUCTURES
  - SENSORS
  - DATA SYSTEMS





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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA Hqs

**PATHFINDER**

- 
- DEVELOPS HIGH LEVERAGE TECHNOLOGIES FOR PILOTED AND ROBOTIC SOLAR SYSTEM EXPLORATION
  - CRITICAL ELEMENT OF THE PRESIDENT'S SPACE POLICY
  - LONG-TERM PROGRAM, PROVIDING BOTH RESEARCH AND DEMONSTRATIONS
  - NECESSARY TO MAINTAIN U.S. LEADERSHIP IN SPACE

**STRATEGY**

- 
- VALIDATE TECHNOLOGY FOCUSED ON ENABLING AND ENHANCING NEW MISSIONS

**LONG RANGE PLAN**

- EMPHASIZE HEALTHY AND COMPLETE CSTI AND PATHFINDER PROGRAMS
- RESPOND TO EVOLVING NEW MISSION CONCEPTS
- REFINE AND ACCELERATE TECHNOLOGY DEVELOPMENT AND VALIDATION IN RESPONSE TO AGENCY DECISION ON BOLD NEW INITIATIVES

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Dr. Judith H. Andrus  
Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA HQ

**UNIVERSITY SPACE ENGINEERING  
RESEARCH PROGRAM**

- **INTEGRAL PART OF STRATEGY TO REBUILD R&T BASE**
  - INCREASE NUMBER OF ENGINEERING GRADUATES
  - INCREASE INVOLVEMENT OF UNIVERSITIES IN CIVIL SPACE PROGRAM
- **LONG TERM FUNDING ENCOURAGES UNIVERSITY COMMITMENT**
- **UNIVERSITY INVOLVEMENT ADDS VALUE**
  - **SPACE R&T**
    - INNOVATIVE/CREATIVE APPROACHES
    - PARTICIPATION FROM WIDE RANGE OF ENGINEERING AND SCIENTIFIC FIELDS
  - **UNIVERSITY**
    - IMPROVES CURRICULA
    - GREATER RELEVANCE OF RESEARCH TO CIVIL SPACE NEEDS

**UNIVERSITY SPACE ENGINEERING  
RESEARCH PROGRAM**

**NINE CENTERS SELECTED FOR FY 1988**

UNIVERSITY OF ARIZONA	CENTER FOR UTILIZATION OF LOCAL PLANETARY RESOURCES
UNIVERSITY OF CINCINNATI	HEALTH MONITORING TECHNOLOGY CENTER FOR SPACE PROPELLSION SYSTEMS
UNIVERSITY OF COLORADO, BOULDER	CENTER FOR SPACE CONSTRUCTION
UNIVERSITY OF IDAHO	VERY LARGE SCALE INTEGRATED HARDWARE ACCELERATION CENTER FOR SPACE RESEARCH
MASSACHUSETTS INSTITUTE OF TECHNOLOGY	CENTER FOR SPACE ENGINEERING RESEARCH FOCUSED ON CONTROLLED STRUCTURES TECHNOLOGY
UNIVERSITY OF MICHIGAN	CENTER FOR NEAR-MILLIMETER WAVE COMMUNICATION
NORTH CAROLINA STATE AT RALEIGH & NORTH CAROLINA AGRICULTURAL & TECHNICAL STATE UNIVERSITY	MASS MISSION RESEARCH CENTER
PENNSYLVANIA STATE UNIVERSITY	CENTER FOR SPACE PROPELLSION ENGINEERING
PENNSYLVANIA POLYTECHNIC INSTITUTE	INTELLIGENT ROBOTIC SYSTEMS FOR SPACE EXPLORATION

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**Dr. Judith H. Antreas**  
**Assistant Director for Space**  
**Office of Aeronautics & Space Technology, NASA HQ**

**STRATEGY**

~~SECRET~~

~~SECRET~~

- **EXPAND UNIVERSITY PROGRAMS**

**LONG RANGE PLAN**

- **GROWTH FOR NINE INCUMBENT UNIVERSITY ENGINEERING RESEARCH CENTERS AWARDED IN APRIL, 1988**
- **ADD NEW AREAS OF PROGRAMMATIC INTEREST**
- **BROADEN UNIVERSITY SUPPORT TO INCLUDE INDIVIDUAL INNOVATION IN RESEARCH**

**IN-SPACE EXPERIMENTS IN OAST**

~~SECRET~~

~~SECRET~~

- **IN-SPACE EXPERIMENTS HAVE ALWAYS BEEN PART OF OAST'S PROGRAM**
  - **TO OBTAIN DATA THAT CAN NOT BE ACQUIRED ON THE GROUND**
  - **TO DEMONSTRATE FEASIBILITY OF CERTAIN ADVANCED TECHNOLOGIES**
- **CONDUCTING TECHNOLOGY EXPERIMENTSS IN SPACE IS A VALUABLE AND COST EFFECTIVE WAY TO INTRODUCE ADVANCED TECHNOLOGY INTO FLIGHT PROGRAMS**
- **THE SHUTTLE HAS DEMONSTRATED THE FEASIBILITY AND TIMELY BENEFITS OF CONDUCTING HANDS-ON EXPERIMENTS IN SPACE**
- **SPACE STATION WILL BE A PERMANENT LABORATORY IN SPACE AND WILL PROVIDE LOGICAL AND EVOLUTIONARY EXTENSION OF GROUND BASED R&T IN SPACE**

**In-Space Technology Experiments in NASA's Strategic Planning**

Dr. Judith H. Ambrose  
Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA Hqs

**IN-SPACE EXPERIMENTS PLANNING**

~~SECRET~~

ASEB PANEL ON NASA'S R&T PROGRAM	JUNE	1983
INDUSTRY/DOD WORKSHOP	FEB	1984
ADMINISTRATOR'S POLICY STATEMENT	APRIL	1984
ASEB PANEL ON IN-SPACE ENGINEERING AND TECHNOLOGY DEVELOPMENT	MAY	1985
OAST IN-SPACE TECHNOLOGY WORKSHOP	OCT	1985
INITIATION OF IN-REACH/OUT-REACH PROGRAMS	OCT	1985
SSTAC AD HOC COMMITTEE ON THE USE OF SPACE STATION FOR IN-SPACE ENGINEERING R&T	AUG	1987
SPACE STATION OPERATIONS TASK FORCE	OCT	1987
NASA MANAGEMENT STUDY GROUP (NMSG - 24)	DEC	1987
NASA CENTER SCIENCE ASSESSMENT TEAM	MAY	1988

**ADVISORY GROUP RECOMMENDATIONS**

~~SECRET~~

... "NASA SHOULD PROVIDE ACCESS TO SPACE FOR EXPERIMENTAL PURPOSES AS A NATURAL EXTENSION OF AEROSPACE FACILITIES...  
... AN EVOLUTIONARY PROGRAM OF ON-ORBIT RESOURCE EQUIVALENT TO ... THE WIND TUNNELS" ...

ASEB, 1983

... "NASA SHOULD BETTER EXPLOIT THOSE SPACE FACILITIES THAT ARE UNIQUE ... THE SHUTTLE AND THE SPACE STATION FOR THE DEVELOPMENT OF TECHNOLOGY FOR NASA, DOD, AND THE INDUSTRY" ...

DOD/INDUSTRY (HEARTH) WORKSHOP, 1984

... "OAST SHOULD PROVIDE THE LEADERSHIP ... TO SUPPORT THE ENGINEERING TECHNOLOGY NEEDS OF THE USER INDUSTRY, OTHER GOVERNMENT AGENCIES, AS WELL AS ITS OWN FOR ALL IN-SPACE ENGINEERING R&T" ...

ASEB, 1985



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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA Hqs

**NASA POLICY ON ROLE OF SPACE TECHNOLOGY**

~~OAST~~

~~IN OSEP-88~~

... "IT WILL BE NASA'S POLICY TO SUPPORT THE DOD AND SPACE INDUSTRY THROUGH COMPETITIVE R&T PROGRAMS JUST AS WE DO IN AERONAUTICS" ...

... "WE CAN BE PARTICULARLY EFFECTIVE IN ESTABLISHING CLOSER TIES WITH INDUSTRY AND THAT IS THE USE OF THE SHUTTLE FOR IN-SPACE EXPERIMENTS.... WHICH WILL LEAD QUITE NATURALLY TO USING THE SPACE STATION FOR TECHNOLOGY AND ENGINEERING EXPERIMENTS" ...

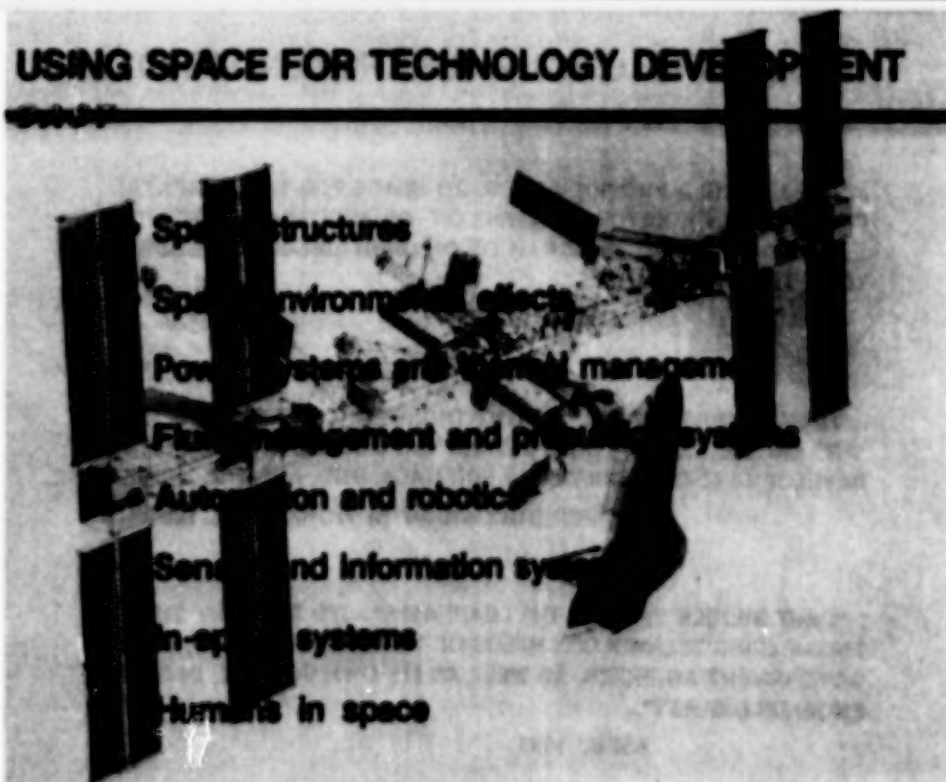
... "TO BEGIN IMPLEMENTING THIS POLICY, I HAVE ASKED ..(OAST).. TO INCREASE OUR EMPHASIS ON IN-FLIGHT EXPERIMENTS" ...

MEMORANDUM FROM THE ADMINISTRATOR

APRIL 3, 1984

**USING SPACE FOR TECHNOLOGY DEVELOPMENT**

~~OAST~~



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Office of Aeronautics & Space Technology, NASA Hqs

**IN-SPACE EXPERIMENTS INITIATIVE - PHASE I**

~~OAST~~ ~~IN STEP 88~~

- **FLIGHT OPPORTUNITY RESTORED**
- **INITIATE MORE VIGOROUS PROGRAM ON SHUTTLE AND ELVs**
  - OBTAIN DATA THAT CAN NOT BE OBTAINED ON THE GROUND
  - VALIDATE ADVANCED TECHNOLOGIES FOR EARLY USE IN FLIGHT PROJECTS
- **GET A RUNNING START ON SPACE STATION**
  - GEAR UP NASA, INDUSTRY, UNIVERSITY ACTIVITY
  - CONDUCT SPACE STATION PRECURSOR EXPERIMENTS

**IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM**

~~OAST~~ ~~IN STEP 88~~

- **NASA EXPERIMENTS**
  - ARISE FROM THE R&T BASE OR FOCUSED PROGRAMS
  - INCLUDE PRESENTLY ONGOING EXPERIMENTS
- **INDUSTRY/UNIVERSITY EXPERIMENTS**
  - FOLLOWING THROUGH ON OUR COMMITMENTS IN THE OUT-REACH PROGRAM
- **INTERNATIONAL EXPERIMENTS**
  - COOPERATIVE ACTIVITIES WITH OUR ALLIES

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**NASA IN-SPACE TECHNOLOGY EXPERIMENTS**

~~OAST~~ ~~IN STEP 88~~

● **INCORPORATES PRESENTLY ON-GOING IN-SPACE R&T PROGRAM**

- ORBITER EXPERIMENTS PROGRAM (OEX)
- LONG DURATION EXPOSURE FACILITY (LDEF)
- LIDAR IN-SPACE TECHNOLOGY EXPERIMENT (LITE)
- ARCJET AUXILIARY PROPULSION SYSTEM
- EXPERIMENTS SELECTED FROM IN-REACH SOLICITATION

● **FUTURE EXPERIMENTS WILL CONTINUE TO ARISE AS A NATURAL EXTENSION OF R&T BASE AND FOCUSED PROGRAMS**

- CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI)
- PATHFINDER

**INDUSTRY/UNIVERSITY IN-SPACE EXPERIMENTS**

~~OAST~~ ~~IN STEP 88~~

● **PROVIDE ACCESS TO SPACE FOR INDUSTRY AND UNIVERSITIES TO DEVELOP SPACE TECHNOLOGY**

- ENTHUSIASTIC RESPONSE OF AEROSPACE COMMUNITY TO OUT-REACH SOLICITATION

● **OAST HAS COMMITTED TO AEROSPACE COMMUNITY TO SERVE AS CONDUIT FOR TECHNOLOGY DEVELOPMENT IN SPACE**

- PERIODIC RESOLICITATIONS TO INDUSTRY/UNIVERSITY COMMUNITY FOR EXPERIMENT DEFINITION, DEVELOPMENT, AND FLIGHT

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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA HQ

**INTERNATIONAL IN-SPACE EXPERIMENTS**

~~DASV~~

~~IN STEP-00~~

- **PROMOTES COOPERATION WITH ALLIES**
- **LEVERAGES TECHNOLOGY DEVELOPMENT BY OTHERS IN KEY AREAS**
- **LEVERAGES AND HUSBANDS SCARCE FLIGHT OPPORTUNITIES**

**IN-SPACE EXPERIMENTS INITIATIVE - PHASE II**

~~DASV~~

~~IN STEP-00~~

- **ROUTINE OPERATIONS IN LOW EARTH ORBIT WILL INITIATE ERA OF BOLD NEW INITIATIVES**
  - **NEED FOR TECHNOLOGY DEMONSTRATIONS FOR ENABLING TECHNOLOGIES WILL INCREASE**
  - **THE RANGE OF TECHNOLOGIES TO BE DEMONSTRATED IN SPACE WILL INCREASE**
  - **SPACE STATION WILL PROVIDE THE FACILITY FOR SIMPLER, FASTER ACCESS TO SPACE**
  - **SPACE STATION WILL ENABLE EXPERIMENTS NEEDING LONG-TERM HUMAN INTERACTION**
- **EXPERIMENTS PLANNED AND DEFINED FOR SPACE STATION DURING PHASE I WILL ENTER HARDWARE DEVELOPMENT STAGE**



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**SUMMARY**

**~~SAOV~~ ~~IN-STEP-88~~**

- **TECHNICAL NEED IDENTIFIED**                      **1983**
- **PLANNING COMPLETE**                              **1983-86**
- **COMMITMENTS MADE**                              **1986-88**
  - **INDUSTRY / UNIVERSITIES (VIA OUT-REACH)**
  - **CENTERS (VIA IN-REACH)**
  - **INTERNATIONAL COMMUNITY**
- **OPPORTUNITY FOR SPACE FLIGHT RESTORED**
  - **SHUTTLE, ELV MANIFESTING**
  - **SPACE STATION PLANNING**

**STRATEGY**

**~~SAOV~~ ~~IN-STEP-88~~**

- **ENSURE INNOVATIVE R&T BASE**
- **VALIDATE TECHNOLOGY FOCUSED ON ENABLING NEW MISSIONS**
- **BUILD STRONGER LINKAGES TO EFFECTIVELY TRANSFER NEW TECHNOLOGIES TO USERS**
- **EXPAND UNIVERSITY PROGRAMS**
- **STEP UP TO COMMITMENT AS LEADER FOR TECHNOLOGY DEVELOPMENT ON SPACE STATION**

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Assistant Director for Space  
Office of Aeronautics & Space Technology, NASA Hqs

**SUMMARY**

~~SASV~~

~~IN-OVER-99~~

**SPACE R&T: A FIVE YEAR OUTLOOK**

- **EQUITABLE AGENCY TECHNOLOGY INVESTMENT ESTABLISHED**
- **OAST IN TECHNOLOGY LEADERSHIP ROLE FOR AGENCY**
- **COOPERATIVE TECHNOLOGY HAND-OFF AGREEMENTS ESTABLISHED WITH USERS**
- **COORDINATION WITH NATIONAL SPACE SECTORS WELL ESTABLISHED**
- **OAST RECOGNIZED AS NATIONAL FOCAL POINT FOR IN-SPACE TECHNOLOGY DEVELOPMENT**

IN-SPACE RESEARCH AND TECHNOLOGY PROGRAM  
UTILIZING SPACE STATION AND OTHER SPACE  
FACILITIES AS A LOGICAL EVOLUTIONARY EXTENSION  
OF GROUND-BASED RESEARCH AND TECHNOLOGY



INSTEP

### ***In-Space Technology Experiment Program***

Jack Levine, Director, Flight Projects Division  
Jon S. Pyle, Manager, In-Reach & Out-Reach Programs  
Office of Aeronautics & Space Technology, NASA Hqs

## **CURRENT SPACE FLIGHT EXPERIMENTS**

<b><u>FLIGHT EXPERIMENTS</u></b>	<b><u>HQ</u></b>	<b><u>LEAD CENTER</u></b>
LONG DURATION EXPOSURE FACILITY	JOHN LORIA	- LANGLEY
ORBITER EXPERIMENTS	RICHARD GUALDONI	- JOHNSON
LIDAR IN-SPACE TECHNOLOGY EXPERIMENT	RICHARD GUALDONI	- LANGLEY
AEROASSIST FLIGHT EXPERIMENT	JOHN SMITH	- MARSHALL
ARCJET FLIGHT EXPERIMENT	JOHN LORIA	- LEWIS
TELEROBOT INTELLIGENT INTERFACE FLIGHT EXPERIMENT	RICHARD GUALDONI	- JPL
CRYOGENIC FLUID MANAGEMENT FLIGHT EXPERIMENT	JOHN LORIA	- LEWIS
IN-REACH (NASA TECHNOLOGY EXPERIMENTS)	JON PYLE	
OUT-REACH (INDUSTRY/UNIVERSITY TECHNOLOGY EXPERIMENTS)	JON PYLE	

## **LDEF** **LONG DURATION EXPOSURE FACILITY**

### **OBJECTIVES:**

- DETERMINE LONG-TERM SPACE EXPOSURE EFFECTS ON MATERIALS, COATINGS, & OPTICS
- MEASURE SPACE ENVIRONMENTAL PHENOMENA OVER EXTENDED TIME

### **STATUS:**

- 34 EXPERIMENTS ADVERSELY AFFECTED BY LDEF RECOVERY DELAY
- 23 EXPERIMENTS EITHER IMPROVED OR NOT AFFECTED
- LDEF STRUCTURE AVAILABLE FOR STUDY OF ENVIRONMENTAL EROSION & DEBRIS IMPACT
- SCHEDULED FOR RETRIEVAL - NOVEMBER 1989

### **LEAD CENTER CONTACT:**

- ROBERT L. JAMES, JR.  
LANGLEY RESEARCH CENTER  
PHONE NO. (804) 865-4887

### ***In-Space Technology Experiment Program***

Jack Levine, Director, Flight Projects Division  
Jon S. Pyle, Manager, In-Reach & Out-Reach Programs  
Office of Aeronautics & Space Technology, NASA HQ

## **OEX ORBITER EXPERIMENT PROGRAM**

### **OBJECTIVES:**

- OBTAIN BASIC AEROTHERMODYNAMIC & ENTRY ENVIRONMENT DATA FROM R&D INSTRUMENTATION INSTALLED IN SPACE SHUTTLE ORBITER
- FLIGHT-VALIDATE GROUND TEST RESULTS TO IMPROVE BASIS FOR DESIGN OF ADVANCED SPACECRAFT

### **STATUS:**

- DATA COLLECTION ON-GOING SINCE 1985 - WILL CONTINUE INTO 1990'S
- SOME EXPERIMENTS STILL TO BE DESIGNED & DEVELOPED

### **LEAD CENTER CONTACT:**

- ROBERT SPANN  
JOHNSON SPACE CENTER  
PHONE # (713) 483-3022

## **LITE LIDAR IN-SPACE TECHNOLOGY EXPERIMENT**

### **OBJECTIVE:**

- EVALUATE CRITICAL ATMOSPHERIC PARAMETERS & VALIDATE OPERATION OF A SOLID-STATE LIDAR SYSTEM FROM A SPACEBORNE PLATFORM, MEASURING:
  - CLOUD DECK ALTITUDES
  - PLANETARY BOUNDARY-LAYER HEIGHTS
  - STRATOSPHERIC & TROPOSPHERIC AEROSOLS
  - ATMOSPHERIC TEMPERATURE & DENSITY (10KM TO 40KM)

### **STATUS:**

- LASER TRANSMITTER MODULE, CASSEGRAIN TELESCOPE, & ENVIRONMENTAL MONITORING SYSTEM IN DEVELOPMENT
- FLIGHT MANIFESTED FOR 1993

### **LEAD CENTER CONTACT:**

- RICHARD R. HELMS  
LANGLEY RESEARCH CENTER  
PHONE NO. (804) 865-4947



***In-Space Technology Experiment Program***

Jack Levine, Director, Flight Projects Division  
Jon S. Pyle, Manager, In-Reach & Out-Reach Programs  
Office of Aeronautics & Space Technology, NASA Langley

**AFE  
AEROASSIST FLIGHT EXPERIMENT**

---

**OBJECTIVE:**

- INVESTIGATE CRITICAL VEHICLE DESIGN & ENVIRONMENTAL TECHNOLOGIES APPLICABLE TO THE DESIGN OF AEROASSISTED SPACE TRANSFER VEHICLES

**STATUS:**

- PHASE B DEFINITION COMPLETE
- EXPERIMENT/INSTRUMENT COMPLEMENT ESTABLISHED
- PRELIMINARY DESIGN INITIATED

**LEAD CENTER CONTACT:**

- LEON B. ALLEN  
MARSHALL SPACE FLIGHT CENTER  
PHONE NO. (205) 544-1817

**ARCJET FLIGHT EXPERIMENT**

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**OBJECTIVES:**

- ASSESS ARCJET AUXILIARY PROPULSION SYSTEM OPERATION IN SPACE ENVIRONMENT
  - HYDRAZINE PROPELLANT
  - 1.4 KW, 50 mLB THRUST, Isp 450
- EVALUATE PLUME EFFECTS & THRUSTER/THERMAL INTERACTIONS ON A COMMERCIAL COMMUNICATIONS SATELLITE

**STATUS:**

- PRELIMINARY DESIGN & ARCJET COMPONENT DEVELOPMENT COMPLETED
- FLIGHT HARDWARE DESIGN, DEVELOPMENT & TESTING SCHEDULED TO START IN 1990
- FLIGHT TEST TENTATIVELY PLANNED FOR 1991

**LEAD CENTER CONTACT:**

- JERRI S. LING  
LEWIS RESEARCH CENTER  
PHONE NO. (216) 433-2841

**In-Space Technology Experiment Program**

Jack Levine, Director, Flight Projects Division  
Jon S. Pyle, Manager, In-Reach & Out-Reach Programs  
Office of Aeronautics & Space Technology, NASA Hqs

**TRIIFEX**  
**TELEROBOTIC INTELLIGENT INTERFACE**  
**FLIGHT EXPERIMENT**

**OBJECTIVES:**

- EVALUATE & VALIDATE TELEOPERATION OF A ROBOTIC MANIPULATOR UNDER CONDITIONS OF MICRO-G & COMMUNICATION TIME DELAYS
- VALIDATE ADVANCED SPACE TELEROBOT CONTROLS INCLUDING HIGH-FIDELITY HYBRID POSITION & FORCE CONTROL TECHNIQUES

**STATUS:**

- CONCEPTUAL DESIGN IN PROGRESS AT JPL
- DEVELOPMENT & INTEGRATION SCHEDULED TO START IN LATE 1988
- FLIGHT TEST PLANNED IN COMBINATION WITH GERMAN ROTEX EXPERIMENT ON SPACELAB D-2 MISSION (1991)

**LEAD CENTER CONTACT:**

- DANIEL KERRISK  
JET PROPULSION LABORATORY  
PHONE NO. (818) 354-2566

**CFMFE**  
**CRYOGENIC FLUID MGMT FLIGHT EXP.**

**OBJECTIVES:**

- DEVELOP TECHNOLOGY REQUIRED FOR EFFICIENT STORAGE, SUPPLY & TRANSFER OF SUBCRITICAL CRYOGENIC LIQUIDS IN LOW-GRAVITY SPACE ENVIRONMENT
- FLIGHT VALIDATE NUMERICAL MODELS OF THE PHYSICS INVOLVED

**STATUS:**

- CONTRACTOR FEASIBILITY STUDIES CURRENTLY UNDER WAY
- 1992 NEW START PROPOSED

**LEAD CENTER CONTACT:**

- E. PAT SYMONS  
LEWIS RESEARCH CENTER  
PHONE NO. (216) 433-2853

***In-Space Technology Experiment Program***

Jack Levine, Director, Flight Projects Division  
Jon S. Pyle, Manager, In-Reach & Out-Reach Programs  
Office of Aeronautics & Space Technology, NASA HQ

**PROGRAM OBJECTIVES**

- 
- **PROVIDE FOR IN-SPACE FLIGHT RESEARCH  
EVALUATION & VALIDATION OF ADVANCED  
SPACE TECHNOLOGIES**

***OUT-REACH PROGRAM***

- **INDUSTRY/UNIVERSITY FLIGHT  
TECHNOLOGY EXPERIMENTS**

***IN-REACH PROGRAM***

- **NASA FLIGHT TECHNOLOGY  
EXPERIMENTS**

**IN-REACH EXPERIMENTS**

- 
- |           |   |
|-----------|---|
| June 1986 | <b>LETTER TO CENTERS REQUESTING PROPOSED<br/>IN-SPACE TECHNOLOGY FLIGHT EXPERIMENTS</b> |
| Aug. 1986 | <b>58 FLIGHT EXPERIMENT PROPOSALS FROM<br/>NASA CENTERS</b>                             |
| Jan. 1987 | <b>COMPLETED EVALUATION OF PROPOSALS</b>  |
| Apr. 1987 | <b>ADVISORY COMMITTEE REVIEW &amp; PRIORITIZATION<br/>OF PROPOSALS</b>                  |
| Jul. 1987 | <b>SELECTION OF 6 DEFINITION &amp; 1 DEVELOPMENT EXP.</b>                               |
- **SPACE STATION STRUCTURAL CHARACTERIZATION**
  - **LASER COMMUNICATION FLIGHT EXPERIMENT**
  - **DEBRIS COLLISION SENSOR**
  - **LASER IN-SPACE SENSOR EXPERIMENT**
  - **CONTAMINATION FLIGHT EXPERIMENT**
  - **EFFECT OF SPACE ENVIRONMENT ON THIN-FOL MIRRORS**
  - **THERMAL ENERGY STORAGE TEST EXPERIMENT**

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**Office of Aeronautics & Space Technology, NASA Hqs**

**OUT-REACH EXPERIMENTS**

- 
- |                   |   |
|-------------------|---|
| <b>Dec. 1985</b>  | <b>IN-STEP 85 WORKSHOP</b>  |
| <b>Oct. 1986</b>  | <b>REQUEST FOR INDUSTRY/UNIVERSITY PROPOSALS</b>  |
| <b>Jan. 1987</b>  | <b>231 PROPOSALS FOR IN-SPACE EXPERIMENTS<br/>(140 FROM INDUSTRY &amp; 91 FROM UNIVERSITIES)</b>  |
| <b>Sept. 1987</b> | <b>SELECTED 5 PROPOSALS FOR DEVELOPMENT OF<br/>FLIGHT EXPERIMENT HARDWARE</b> <ul style="list-style-type: none"><li>- TANK PRESSURE CONTROL EXPERIMENT<br/>BOEING AEROSPACE COMPANY/LARC</li><li>- MID-DECK 0-G DYNAMICS EXPERIMENT<br/>MASSACHUSETTS INSTITUTE OF TECHNOLOGY/LARC</li><li>- INVESTIGATION OF SPACECRAFT GLOW<br/>LOCKHEED MISSILE &amp; SPACE COMPANY/JSC</li><li>- HEAT PIPE THERMAL PERFORMANCE<br/>HUGHES AIRCRAFT COMPANY/OSPC</li><li>- EMULSION CHAMBER TECHNOLOGY EXPERIMENT<br/>UNIVERSITY OF ALABAMA IN HUNTSVILLE/OSPC</li></ul> |
| <b>Sept. 1987</b> | <b>SELECTED 38 PROPOSALS FOR DEFINITION OF<br/>FLIGHT TECHNOLOGY EXPERIMENTS</b> <ul style="list-style-type: none"><li>- STUDIES TO BE COMPLETED IN SEPT. 1988</li><li>- SOLICITATION FOR DEVELOPMENT OF FLIGHT<br/>HARDWARE OPEN TO ENTIRE COMMUNITY</li></ul>   |

**FIRST SOLICITATION REVIEW**

**OBSERVATIONS**

- **SIGNIFICANT EXPENDITURE BY INDUSTRY  
& UNIVERSITIES (231 PROPOSALS)**
- **APPROX. 250 NASA SCIENTISTS & TECHNOLOGISTS  
INVOLVED IN TECHNICAL EVALUATIONS**
- **NEW SOLICITATION BETWEEN DEFINITION &  
DEVELOPMENT ADDS MORE PROPOSAL COSTS**
- **GENERAL TECHNOLOGY SOLICITATION TOO BROAD  
(SHOTGUN APPROACH TO TECHNOLOGY  
DEVELOPMENT)**



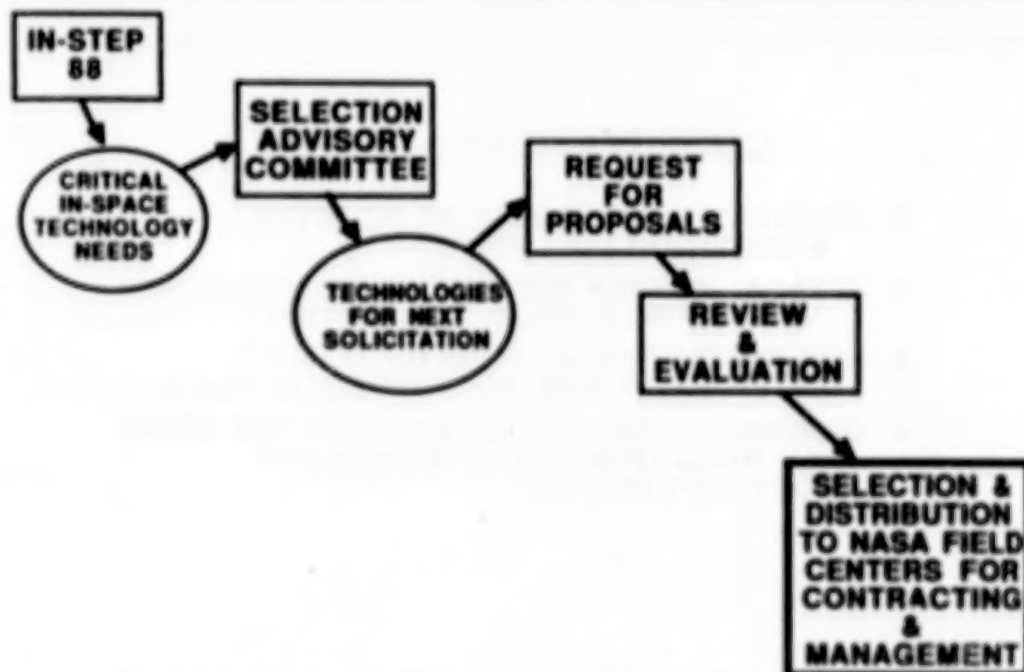
### *In-Space Technology Experiment Program*

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Office of Aeronautics & Space Technology, NASA HQ

## REVISED APPROACH

- DEFINE & PRIORITIZE CRITICAL SPACE TECHNOLOGY DEVELOPMENT REQUIREMENTS FOR FUTURE SPACE MISSIONS
- USE PRIORITIZED LISTING TO FOCUS FUTURE TECHNOLOGY DEVELOPMENT & IN-SPACE FLIGHT TECHNOLOGY EXPERIMENTS
- FUTURE SOLICITATIONS FOR DEFINITION OF FOCUSED IN-SPACE FLIGHT TECHNOLOGY EXPERIMENTS
- DOWN-SELECT BETWEEN COMPETING EXPERIMENTS FOR CONCEPTUAL DESIGN PHASE & FLIGHT HARDWARE DEVELOPMENT PHASE

## SOLICITATION PROCESS



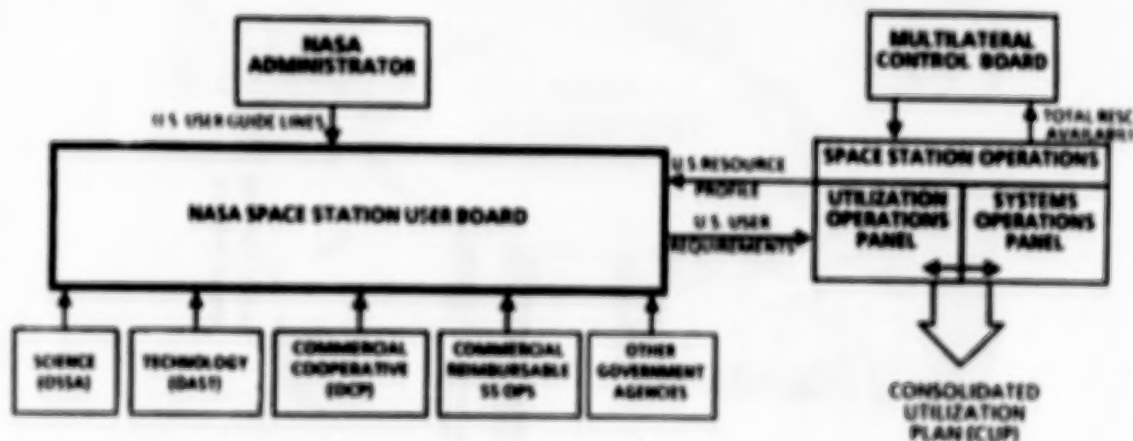
***In-Space Technology Experiment Program***

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**Office of Aeronautics & Space Technology, NASA HQ**

**SUMMARY**

- **LONG & SUCCESSFUL HISTORY IN THE CONDUCT OF SPACE FLIGHT TECHNOLOGY EXPERIMENTS**
- **PROGRAM IS BEING EXPANDED TO EMPHASIZE THE DEVELOPMENT OF ADVANCED SPACE FLIGHT TECHNOLOGIES**
- **OAST PLANS TO PROVIDE ACCESS TO SPACE FOR THE AEROSPACE TECHNOLOGY COMMUNITY (NASA, DOD, INDUSTRY & UNIVERSITIES)**

**USER ROLE -- STRATEGIC PLANNING**



**Jack Levine, Director, Flight Projects Division  
Jon S. Pyle, Manager, In-Reach & Out-Reach Programs  
Office of Aeronautics & Space Technology, NASA HQ**

**PROJECT DEVELOPMENT**

**PROGRAM DEVELOPMENT** | **PROJECT MANAGEMENT**

**FOCUS PLANNING** → **DEFINITION** → **ENGINEERING DEVELOPMENT** → **FLIGHT DEVELOPMENT**

**Milestones:**

- AO's (between Focus Planning and Definition)
- TECHNOLOGY CONCEPT REVIEW (between Definition and Engineering Development)
- FLIGHT EXPERIMENT REVIEW (between Engineering Development and Flight Development)

**Activities:**

- FOCUS PLANNING:** TECHNOLOGY THEME WORKING GROUPS, CRITICAL FLIGHT EXPERIMENT ROADMAPS, AO PREPARATION
- DEFINITION:** TECHNICAL REQUIREMENTS, HARDWARE IDEAS, PRELIMINARY PROJECT PLAN
- ENGINEERING DEVELOPMENT:** ENGINEERING REQUIREMENTS DEFINED, FEASIBILITY ESTABLISHED, HARDWARE CONCEPTUAL DESIGN, PHASE 0 SAFETY PACKAGE, PROJECT PLAN
- FLIGHT DEVELOPMENT:** FLIGHT HARDWARE DESIGN, FABRICATE, INTEGRATION, & TEST OPERATIONS, DATA ANALYSIS & REPORT

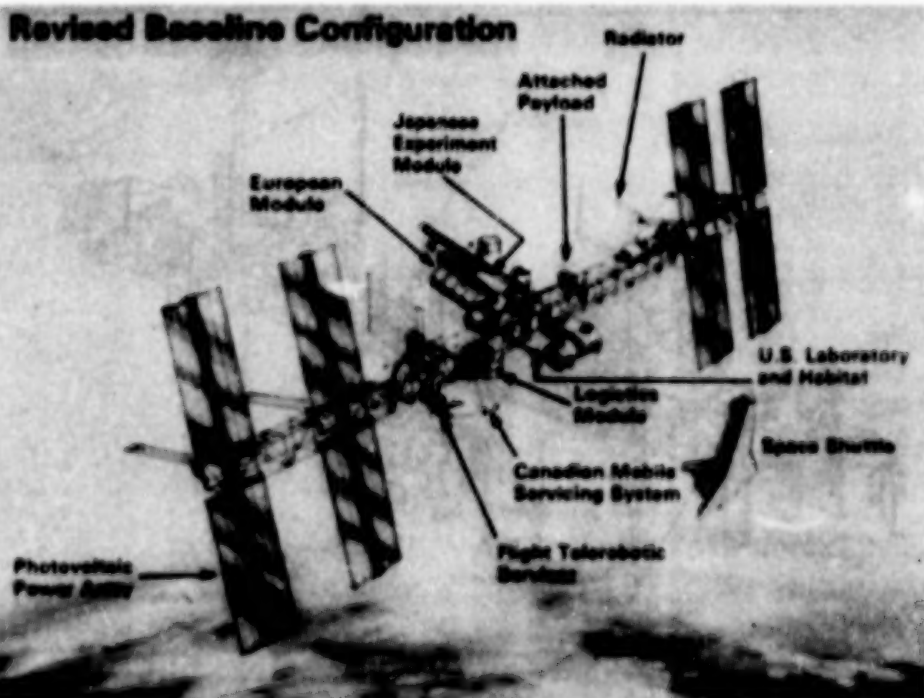


**Space Station Freedom User/Payload Integration & Accommodations**

Alan C. Holt, Deputy Director (Acting), User Integration Division  
Utilization & Operations Group  
NASA Space Station Freedom Program Office, Reston, Virginia

**SPACE STATION FREEDOM  
TECHNOLOGY PAYLOADS**

- **CRITICAL TO THE SUCCESS OF THE SPACE STATION GROWTH OR DEVELOPMENT AND FUTURE SPACE PROJECTS AND MISSIONS.**
- **EFFECTIVE WAY OF AUGMENTING SPACE STATION PAYLOAD ACCOMMODATION CAPABILITIES - TEST AND CONVERSION TO OPERATIONAL USE.**
- **PROMOTE THE DEVELOPMENT OF TECHNOLOGICAL APPLICATIONS WHICH SUPPORT OTHER GOVERNMENT AND PRIVATE PROJECTS AND PRODUCTS.**
- **PROVIDES NEW EDUCATIONAL OPPORTUNITIES FOR NEW GENERATIONS OF SCIENTISTS, ENGINEERS, AND OTHER PROFESSIONS.**





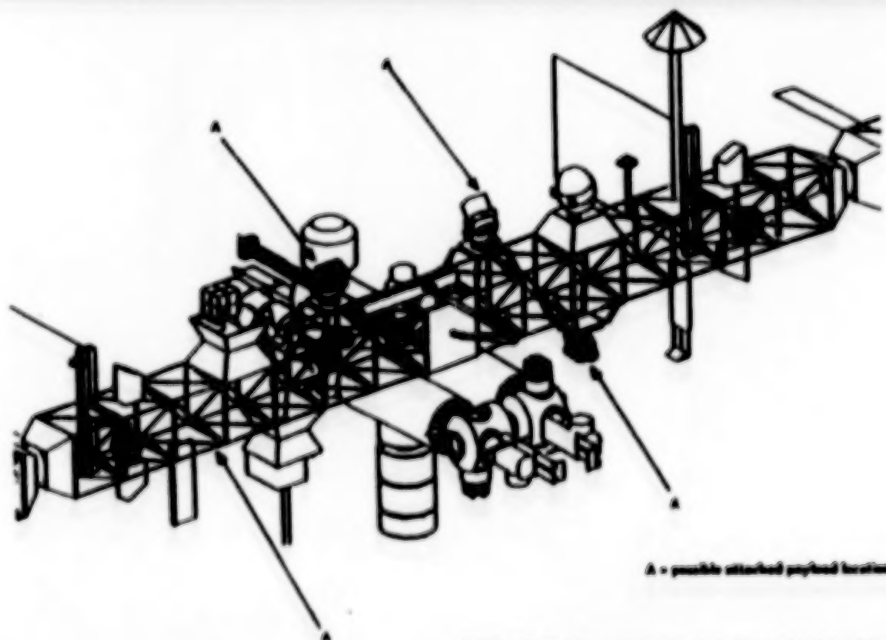
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**SPACE STATION FREEDOM  
TECHNOLOGY PAYLOAD ACCOMMODATION**

- MATERIALS R&D
- ADVANCED RADIATOR AND POWER SYSTEM
- ADVANCED PROPULSION SYSTEMS
- TECHNOLOGY PAYLOADS WITH STRONG MAGNETIC FIELDS
- LASER SYSTEMS - OPTICAL COMMUNICATION
- ELECTRON BEAMS, WAVE GENERATION, ETC.
- INTERNAL TECHNOLOGY PAYLOADS - RADIATION, SEU
- ADVANCED ECLS SUBSYSTEMS

**Potential Attached Payload Locations**



A = possible attached payload locations

NOTE: Could utilize more than one truss cube surface but utility port provided  
resources would have to be shared

3007 0014 116  
11607 1/00000 00 0

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**MANNED BASE ATTACHED PAYLOAD ACCOMMODATIONS**

**PAYLOAD CLASSIFICATION**

CLASS	PAYLOAD FEATURES
MAJOR	<ul style="list-style-type: none"> <li>• LARGE</li> <li>• REQUIRES MAJOR APAE RESOURCES</li> <li>• ACTIVE THERMAL COOLING</li> <li>• SOME NEED PPS FOR POINTING</li> <li>• LONG STAY</li> </ul>
SMALL AND/OR RAPID RESPONSE	<ul style="list-style-type: none"> <li>• SMALL</li> <li>• NO ACTIVE THERMAL COOLING</li> <li>• MODEST POWER/DATA RESOURCES</li> <li>• VARIETY OF FIELDS OF VIEW</li> <li>• SET ASIDE RESOURCES</li> </ul>
DISTRIBUTED SENSOR	<ul style="list-style-type: none"> <li>• CAN BE VERY SMALL IN SIZE (LIKE ACCELEROMETER)</li> <li>• NON-STANDARD LOCATIONS</li> <li>• MODEST POWER/DATA RESOURCES</li> <li>• CAN BE ANALYTICALLY INTENSIVE</li> <li>• CAN HAVE UNIQUE PACKAGING</li> </ul>



**APAE TYPICAL CONFIGURATIONS**



MULTIPLE PAYLOADS



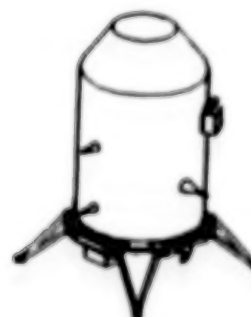
PALLET MOUNTED PAYLOAD



PAYLOAD AND PAYLOAD POWERING SYSTEM



SINGLE PAYLOAD



LARGE PAYLOAD

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**MANNED BASE ATTACHED PAYLOAD ACCOMMODATIONS**

**APAE DESIGN CAPABILITY**

**DESIGNED FOR:**

**MULTIPLE PAYLOADS**



**MAJOR**



**POINTING PAYLOADS**



**4 COMPATIBLE PAYLOADS VIA  
 MULTIPLE PAYLOAD ADAPTERS (MPAs)**

- APAE DESIGNED TO SUPPORT UP TO 25,000 LB PAYLOAD
- PROVIDES: 10kW POWER  
50 MBPS DATA RATE  
10 kW ACTIVE COOLING } PAYLOAD(S)
- STRUCTURAL SUPPORT FOR POINTING CAPABILITY (60 ARC SEC ACCURACY) FOR 6000 kg PAYLOAD

**MULTIPLE PAYLOAD/DECK CARRIER CONFIGURATION**

CONTAMINATION MONITORING UNIT (CMU)  
 (PAYLOAD DEPENDENT)

DECK CARRIER

PAYLOAD INTERFACE ADAPTER (PIA)

SYSTEM SUPPORT MODULE  
 THERMAL ORU

PAYLOADS

MULTIPLE PAYLOAD ADAPTER (MPA)  
 60 PROVIDED INCLUDES SEC AND  
 OPTIONAL COLD PLATE

SYSTEM SUPPORT MODULE  
 ELECTRICAL POWER/DATA ORU

STATION INTERFACE ADAPTER (SIA)  
 (INSTALLED ON SIFPD VIA EVA)

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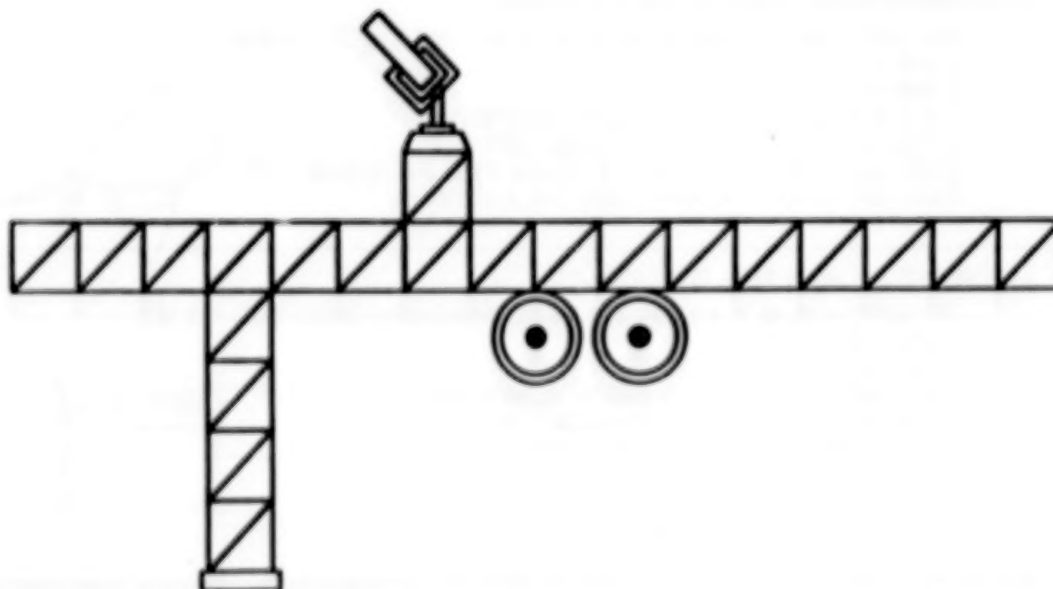
**PAYLOAD POINTING SYSTEM (PPS)**

**PPS PAYLOAD ACCOMMODATION CAPABILITIES**

- 1 ARC MINUTE POINTING ACCURACY
- 30 ARC SECOND POINTING STABILITY  
(OVER 1000 SECS)
- 15 ARC SECOND/SECOND JITTER
- 3 AXES
- 5 MW OF POWER/ACTIVE COOLING
- 50 MEGABITS HIGH RATE DATA/IMAGERY
- 6000 KG PAYLOAD - 3 METERS WIDE,  
C.G. TO BASE 2.5 METERS
- ACCEPTS PAYLOAD SENSOR INPUT FOR POINTING



**CAPABILITY TO ADD TRUSS STRUCTURE TO ENHANCE  
ATTACHED PAYLOAD VIEWING AND CLEARANCE**

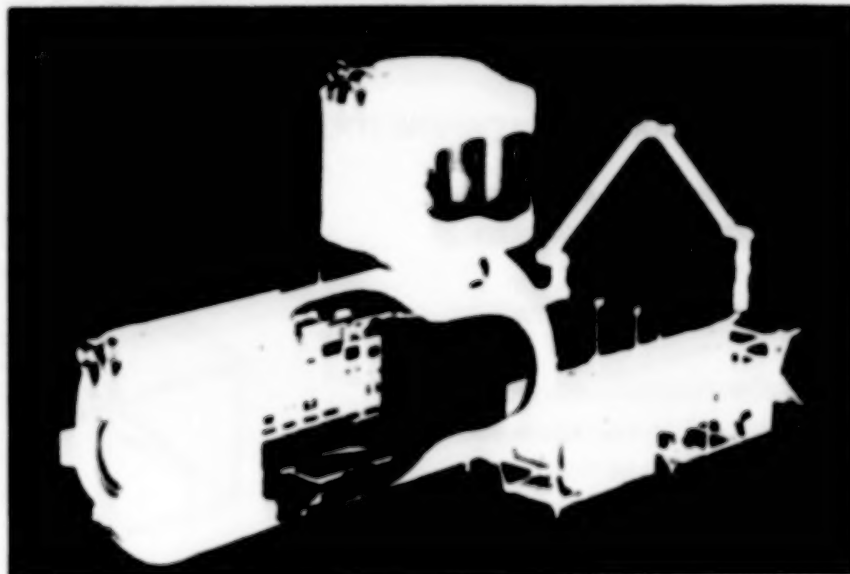




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**JAPANESE EXPERIMENT MODULE**

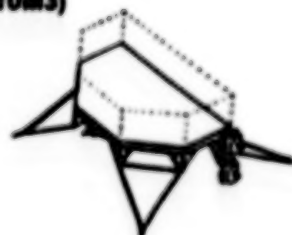


**SMALL AND RAPID RESPONSE PAYLOADS**

**EXTERNAL SARR PAYLOAD ENVELOPE &  
PROPOSED CONSTRAINTS**

**• TRUNNION/KEEL (T/K) SARR PAYLOAD:**

FIT INTO 4M X 1.25M X 2M ENVELOPE (MAX VOL <10M<sup>3</sup>)  
≤ 900 KG  
≤ 900 WATTS  
≤ 0.3 MBPS UPLINK/2.0 MBPS DOWNLINK  
≤ 100 MBYTES DATA STORAGE/ORBIT  
CAN ACCOMMODATE MORE THAN ONE PAYLOAD  
RMS GRAPPLE FIXTURE (ON T/K CARRIER)



**• GENERIC (GEN) SARR PAYLOAD:**

FIT INTO 1.25 M X 1.25 M X 1.25 M ENVELOPE (MAX VOL ≤ 2 M<sup>3</sup>)  
≤ 300 KG  
≤ 300 WATTS  
≤ 0.3 MBPS UPLINK/2.0 MBPS DOWNLINK  
≤ 100 MBYTES DATA STORAGE/ORBIT  
ORU COMPATIBLE I/F (ORU TOOL)



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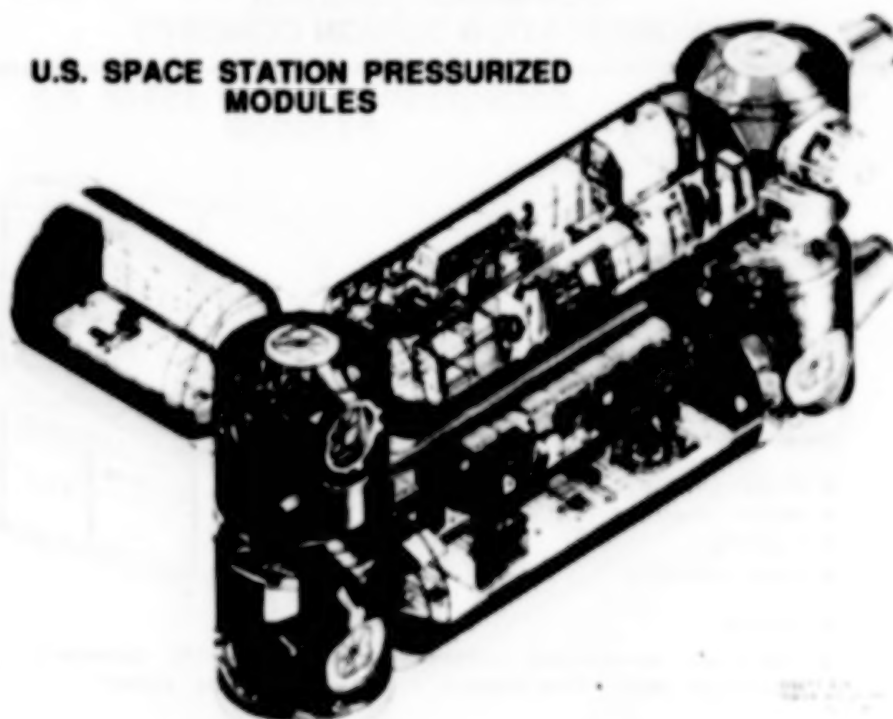
**SMALL AND RAPID RESPONSE PAYLOADS**

**INTERFACE COMPARISON CHART FOR RELATIVELY SMALL ATTACHED PAYLOADS\* ON TRUSS AND JEM EE (PROPOSED)**

\* These do not require an APAE

Interface or Physical Constraint	PAYLOAD		
	SARR Trunnion Keel	SARR Generic	JEM Exposed Facility
Weight	≤ 1800 lbs ≤ 800 kg	≤ 680 lbs ≤ 300 kg	Typically 1100 lbs or 500 kg
Volume Limitations	~ 10m <sup>3</sup>	~ 2m <sup>3</sup>	~ 2m <sup>3</sup>
Physical Dimensions	1.25m x 2.0m x 4.0m	1.25m x 1.25m x 1.25m	0.6m x 1.0m x 1.0m (0.6m x 1.0m footprint)
Thermal Cooling	only passive	only passive	≤ 5kW active cooling
Power Constraint	≤ 1.5kW	≤ 0.3kW	≤ 0.5kW
Data Rates			
Downlink	2.0 Mbps	1.4 Mbps	4 Mbps
Uplink	0.3 Mbps	0.3 Mbps	4 Mbps
Access to Pressurized Module	None	None	Possible thru JEM Airlock
Pointing Capability Provided	None	None	None

**U.S. SPACE STATION PRESSURIZED MODULES**



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 NASA Space Station Freedom Program Office, Reston, Virginia

**TRIAL PAYLOAD MANIFEST, U.S. LABORATORY  
 MODULE: AFTER OUTFITTING FLIGHT OF-1**



■ IN STATION SYSTEM BAY  
 ■ DMS Payload BAY (B1-B10)

**COMMAND/CONTROL  
 WORKSTATION DESIGN CONCEPT**

**DMS Fixed MPAC Components**

- Three 15" color CRTs
- QWERTY keyboard
- Trackball
- Hand controllers
- Processor
- Safety-critical D/C
- Hard-copy printer/plotter

**Other Components**

- Video recorders
- Audio recorders
- Lighting
- Crew restraints

**Functions**

- Subsystem management, customer support, proximity operations, telerobotic (MSC, FTS) control, external operations support



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**COMMAND/CONTROL  
WORKSTATION DESIGN CONCEPT**

**Key MPAC Requirements**

- Alphanumeric
- Graphics
- Animation
- Integrated Video, Graphics, Text
- Color Displays
- Windowing
- Voice Input
- Voice Output
- 3D Graphics
- Run the DMS USE Software



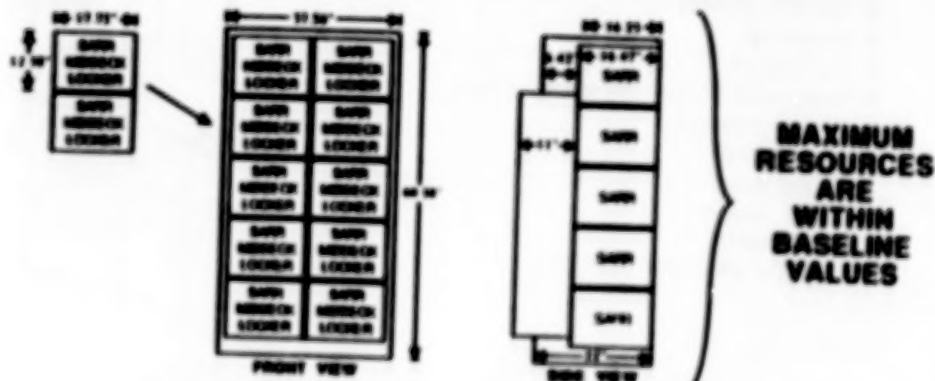


## Space Station Freedom User/Payload Integration & Accommodations

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### INTERNAL SARR PAYLOAD REQUIREMENTS

- **LOCATION REQUIREMENTS:**  
DEDICATED STANDARD DOUBLE RACK FOR UP TO 10 INTERNAL SARR PAYLOADS. RACK SHALL BE CAPABLE OF BEING RECONFIGURED ON ORBIT TO SUPPORT STANDARD SARR PAYLOADS.
- **RESOURCE PROVISIONS FOR DEDICATED STANDARD DOUBLE RACK:**

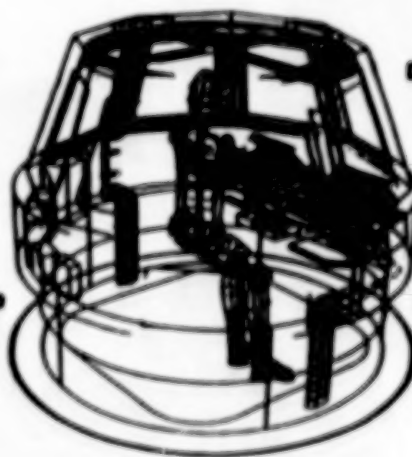


NO ACTIVE COOLING (STANDARD RACK AIR COOLING ONLY)

### CUPOLA WORKSTATION CONCEPT

#### Key Cupola MPAC Reqs

- Alphanumeric
- Graphics
- Animation
- Video
- Telerobotics Control
- OMV Piloting
- MSC Control
- Run the DMS USE Software



#### DMS Cupola MPAC Component

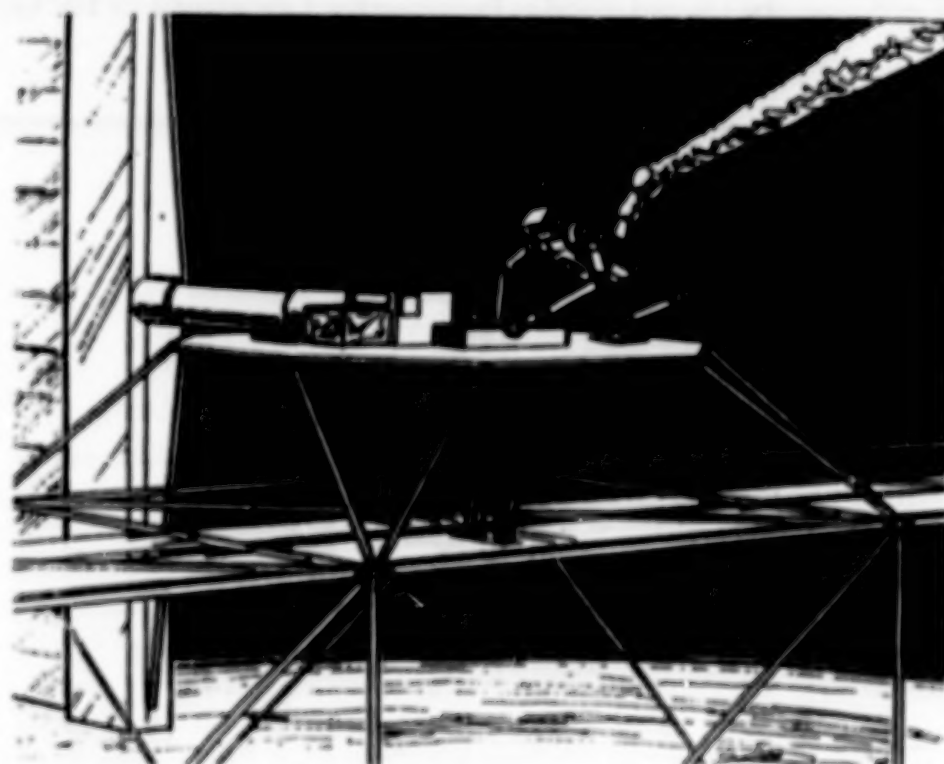
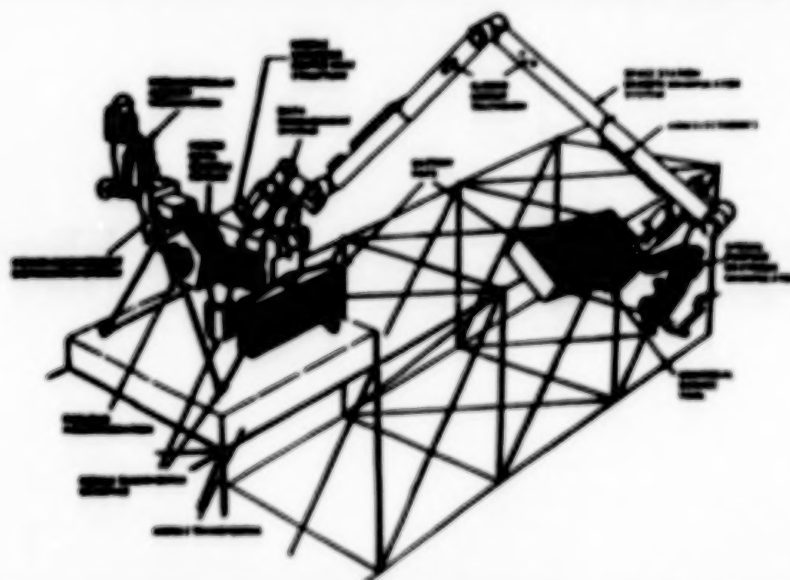
- Two 15" TFEL Displays
- Two QWERTY keyboards
- Two Trackballs
- Hand controllers
- Processor

#### Other Components

- Lighting
- Crew restraints

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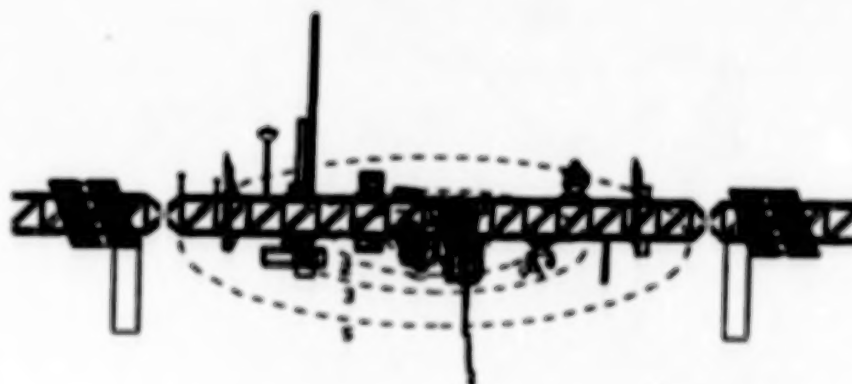
## MOBILE SERVICING CENTER



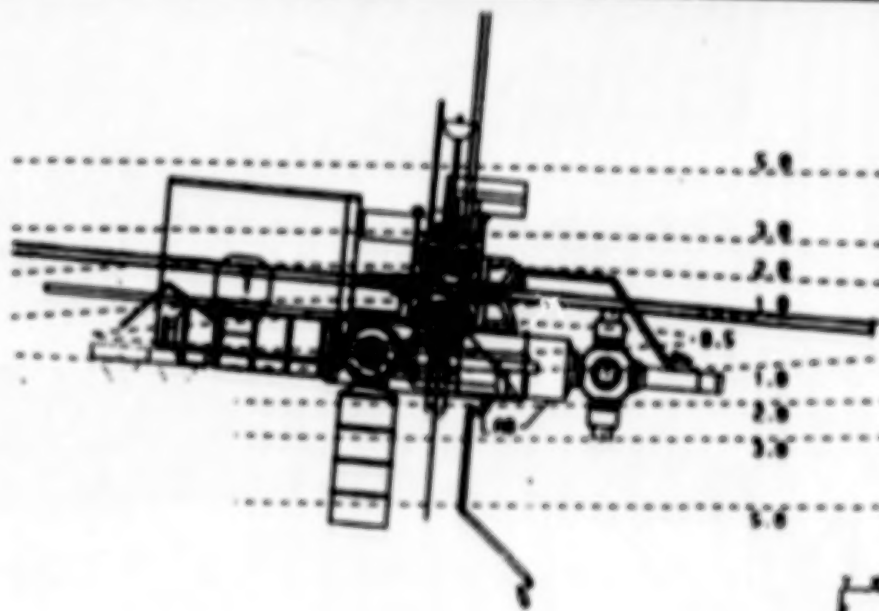
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**Microgravity Quasi-Static Isogravity Contours ( $\times 10^{-4}$  G)  
(June, 1999, Altitude 230 n. miles)  
Front View**



**Microgravity Quasi-Static Isogravity Contours ( $\times 10^{-4}$  G)  
(June, 1999, Altitude 230 n. miles)  
Side View**



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NASA Space Station Freedom Program Office, Reston, Virginia

**Microgravity Quasi-Static Isogravity Contours ( $\times 10^{-4}G$ )  
(June, 1999, Altitude 230 n. miles)  
Close-up of U.S. Laboratory**



**SPACE STATION ELECTROMAGNETIC COMPATIBILITY  
AND ENVIRONMENTAL INTERACTIONS STUDY**

**NATURAL ENVIRONMENTS**

- NEUTRAL
- PARTICULATE
- RADIATION
- MAGNETIC FIELD
- PLASMA
- EM RADIATION

**ENVIRONMENT PERTURBATIONS**

- THRUSTER FIRINGS
- VENTS AND OUTGASSING
- INDUCED CURRENTS
- COUPLING OF EM WAVES
- PLASMA BEAMS
- PARTICULATES
- RAM/WAKE

**ENVIRONMENT INDUCED PHENOMENA**

- CHARGING
- ESD
- EMI
- HIGH VOLTAGE SURFACES
- SURFACE CONTAMINATION
- LONG TERM DEGRADATION

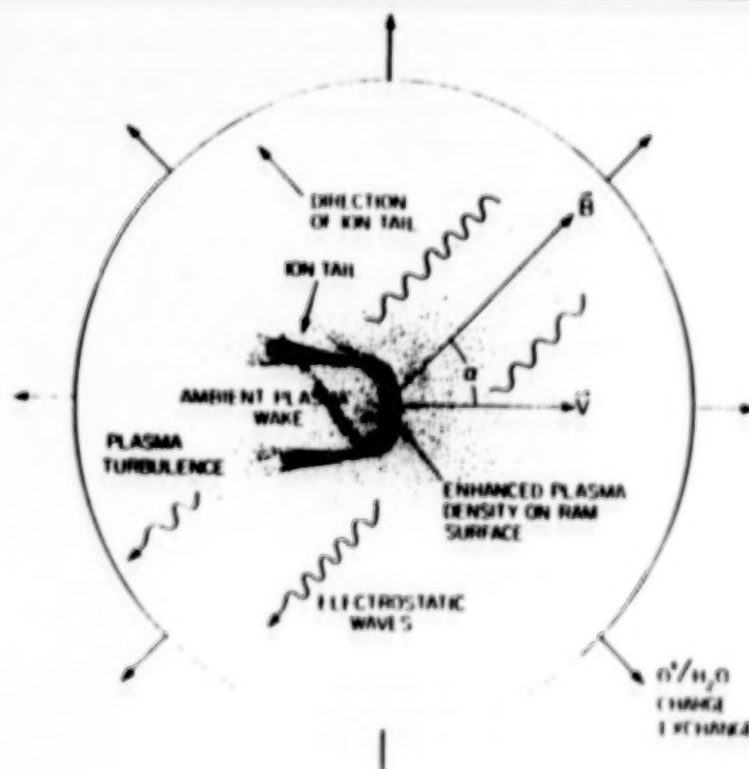


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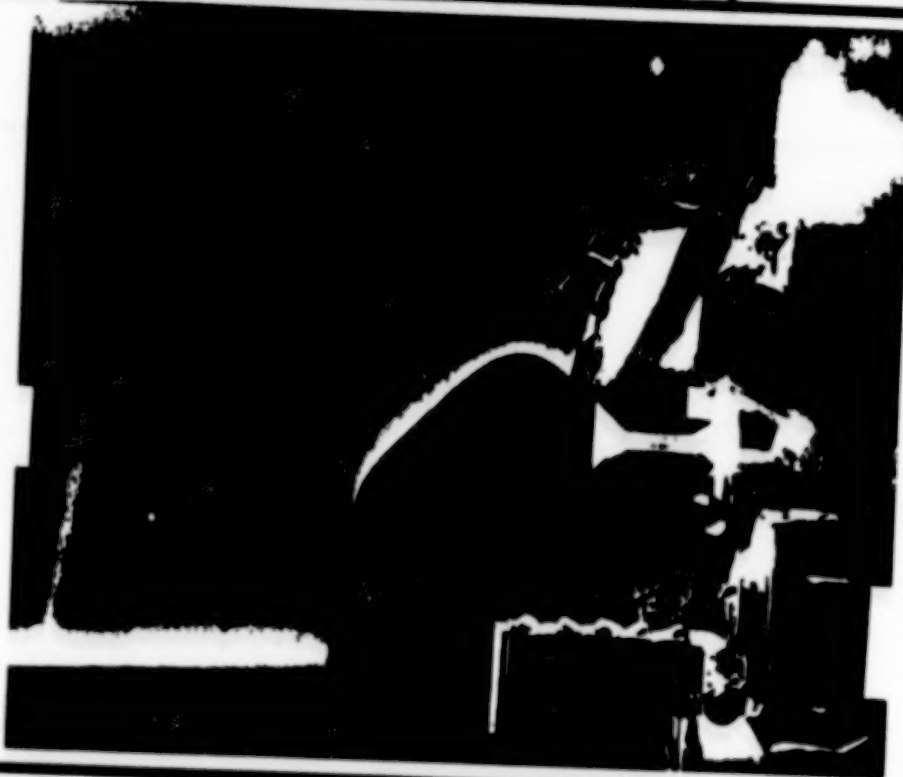
**INDUCED ENVIRONMENT NEAR LARGE SURFACES (ANDERSON [1984])**

PARAMETERS	RAM	WAKE	COMMENT	EFFECT
NEUTRAL DENSITY, Torr	$10^{-5}$	$10^{-7}$	MEASURED	HIGH VOLTAGE SHORTS, CONTAMINATION
PLASMA DENSITY, $\text{cm}^{-3}$	AS HIGH AS $5 \times 10^6$	AS LOW AS $10$	MEASURED	POWER LOSS, ARCING
PLASMA WAVES	20 Hz - 200 MHz (22V/m) $\sqrt{f}$ dBHz AT PEAK	LOW	MEASURED ELECTROSTATIC WAVES	EM BACKGROUND NOISE
ENERGETIC PARTICLES	MEAN ENERGY OF ELECTRONS 10 - 100 eV FLUX: $\sim 10^8/\text{cm}^2 \text{ sec}$ 500 eV MEAN ENERGY OF IONS 10 - 30 eV	LOW	HIGHER FLUXES PREDICTED; LITTLE NUMERICAL DATA PUBLISHED	PLASMA WAKE, DIFFERENTIAL CHARGING
GLOW, PHOTONS ( $\text{cm}^{-2}\text{s}^{-1}$ )	$10^7 - 10^8$	LOW	GLOWING LAYER ON RAM 10-20 cm THICK	OPTICAL (IR) CONTAMINATION



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**POTENTIAL ENVIRONMENTALLY ACTIVE PAYLOADS**

**ASTROMAG (EARLY ATTACHED PAYLOAD CANDIDATE)**

- ENERGY STORED BY MAGNETIC FIELD: 10 MEGA JOULES
- MAXIMUM MAGNETIC FIELD INTENSITY: 70,000 GAUSS
- FIELD CONFIGURATION: QUADRUPOLE, DECREASES TO EARTH'S MAGNETIC FIELD INTENSITY AT 15 METER DISTANCE

**SOLAR TERRESTRIAL OBSERVATORY: PLASMA PHYSICS GROUP (LATER ATTACHED PAYLOAD CANDIDATE)**

- ELECTRON BEAMS
- WAVE GENERATORS - GROWTH VERSION UP TO 50 KW POWER REQUIREMENT

**HIGH TEMPERATURE SUPERCONDUCTING MAGNETIC FIELD ENERGY STORAGE SYSTEM (CANDIDATE PAYLOAD ANTICIPATED)**

- HIGH MAGNETIC FIELD INTENSITIES

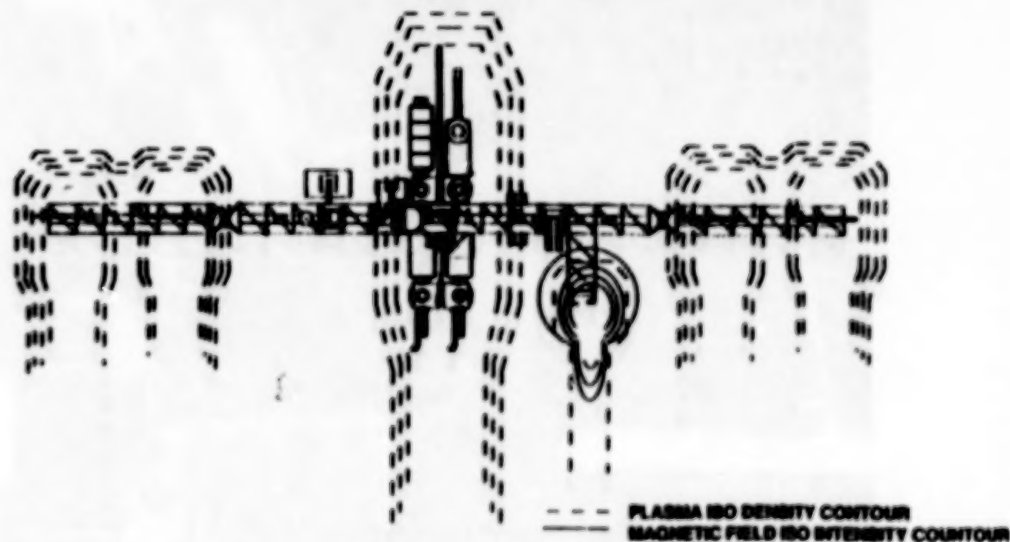
**ADVANCED ELECTRIC AND ELECTROMAGNETIC PROPULSION SUBSYSTEM TECHNOLOGY TESTS (CANDIDATE PAYLOAD ANTICIPATED)**

- HIGH MAGNETIC FIELD AND ELECTRIC FIELD INTENSITIES

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**INDUCED ENVIRONMENTAL EFFECTS OF ACTIVE  
TECHNOLOGY PAYLOADS - TOP VIEW**



**SPACE STATION FREEDOM  
GROWTH CAPABILITIES / TECHNOLOGY PAYLOADS**

**SERVICING FACILITY**

- REPAIR AND CONDUCT RESUPPLY AND REFUELING OPERATIONS FOR FREE FLYERS AND CO-ORBITING PLATFORMS
- EXTENSIVE REPAIR WORK FOR ATTACHED PAYLOADS
- ASSEMBLY OF UPPER STAGES AND PAYLOADS

**LARGE SPACE CONSTRUCTION FACILITY**

- LARGE CRANE FOR POSITIONING
- ADDITIONAL MOBILE ROBOTICS
- CAPABILITY TO ASSEMBLE LARGE ANTENNAS, PHASED-ARRAY OPTICAL SYSTEMS

**CO-ORBITING PLATFORM, ADVANCED TECHNOLOGY TEST FACILITY**

- USER-SUPPLIED OR STATION-SUPPLIED PLATFORM TO CONDUCT PARTIAL OR FULLUP TESTS OF ADVANCED PROPULSION AND POWER SYSTEMS
- TESTING OF TECHNOLOGY INVOLVING HAZARDOUS MATERIALS OR OPERATIONS OR REQUIRING ORBITAL DYNAMICS NOT SUPPORTED BY THE STATION

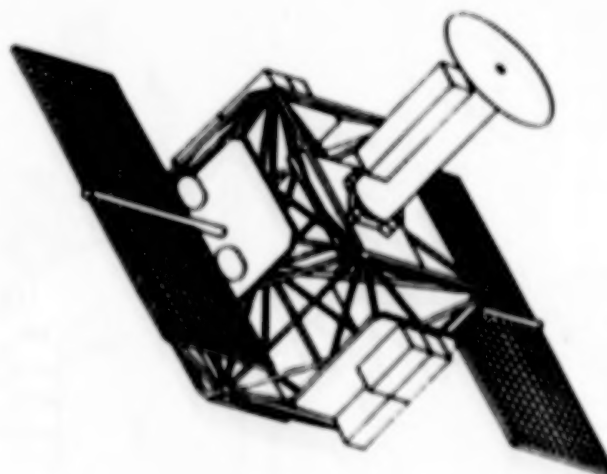
**Space Station Freedom User/Payload Integration & Accommodations**

Alan C. Holt, Deputy Director (Acting), User Integration Division  
Utilization & Operations Group  
NASA Space Station Freedom Program Office, Reston, Virginia

**SPACE STATION FREEDOM POLAR PLATFORM**



**SKP TRUSS DERIVATIVE CONFIGURATION  
(WITH HRSO)**





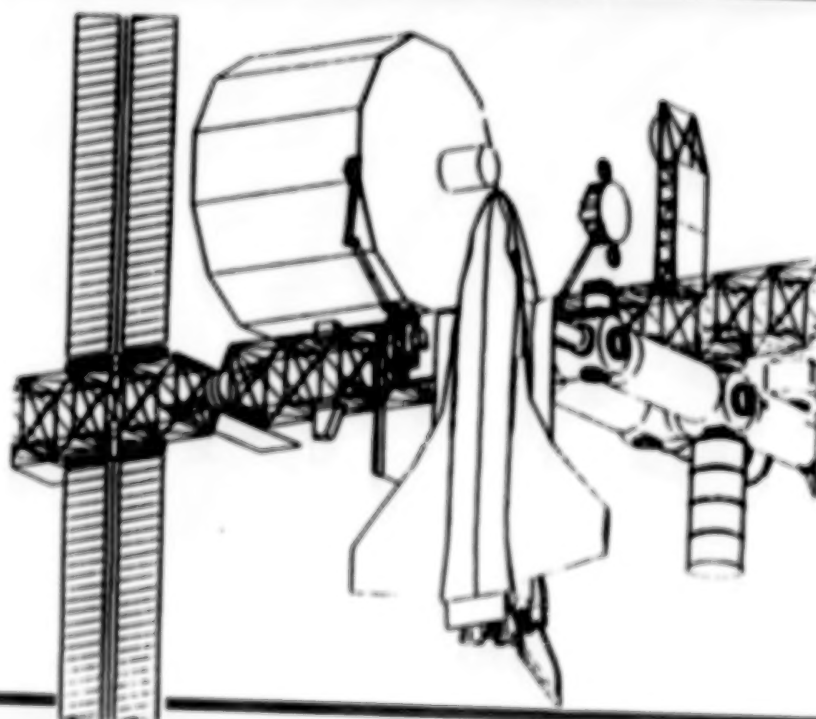
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**Assembly of Large Deployable Reflector - I**



**Assembly of Large Deployable Reflector - II**



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NASA Space Station Freedom Program Office, Reston, Virginia

**SPACE STATION WITH CANDIDATE MANNED  
MARS CONFIGURATION**



**Manned Mars Accommodation Study  
PROPELLANT TANK FARM**

**CO-ORBITING PROPELLANT TANK FARM RECOMMENDED TO  
STORE AND TRANSFER PROPELLANTS FOR MANNED MARS  
MISSION**



**CAPACITY**  
1.9 M LB H<sub>2</sub> - O<sub>2</sub>  
12 TANKS 16' X 60'

**Space Station Freedom User/Payload Integration & Accommodations**

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Utilization & Operations Group  
NASA Space Station Freedom Program Office, Reston, Virginia

Space Station User Integration Process

SPACE STATION FREEDOM  
UTILIZATION & OPERATIONS

SSU

**Process Description**

• SCOPE

◊ End to End User Integration is the Process Which:

- ▼ Enables a User to Conduct Research, Development or Commercial Activities on the Station.
- ▼ Includes All Interactions Between the SSP and the User/User Sponsors
- ▼ External Activities Beginning with the User's Initial Contact With the SSP and Continuing Until Exit from the Program.

◊ The Integration Process Shall Provide a "Level Playing Field", with Payloads having similar Physical and Operational Requirements following the Same Path.

Space Station User Integration Process

SPACE STATION FREEDOM  
UTILIZATION & OPERATIONS

SSU

**Process Description**

• PROCESS DEVELOPMENT GOAL:

◊ Provide a Process for User Integration Which:

- ▼ Supports a Diverse User Community, Including Rapid Response Research (QRB)
- ▼ Enables high priority research and development supporting national objectives and future missions.
- ▼ Minimizes the Burden on the Users (Data, Meetings, etc.)
- ▼ Provides single point of contact for Shuttle and Station Integration
- ▼ Does Not Compromise Safety
- ▼ Incorporates Lessons Learned from Past Programs
- ▼ Recognizes Constraints Imposed by the Physical Requirements of Payload Integration

**Space Station Freedom User/Payload Integration & Accommodations**

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**Space Station User Integration Process**

SPACE STATION FREEDOM  
UTILIZATION & OPERATIONS

SCU

**Integration Process Overview**

- Consider as Multiple Processes :
  - ◊ Payload Accommodation Assessment
    - Verify station or platform capabilities can accommodate payload requirements
    - Identify deficiencies and potential station enhancements or potential reduction in payload requirements required
  - ◊ Payload Development
    - Payload DDT&E Conducted by Developer, PI
    - Driven by Experiment Goals, Development Resources
  - ◊ Analytical Integration
    - Engineering Analysis (Loads, Thermal, EMI, Contam., etc.)
    - Verify S/W Design
    - Analytical Support of Certification/Verification
  - ◊ Payload Integration, Test & Verification
    - Safety Certification
    - Verify P/L Design for Transportation, On-orbit Ops
    - Ensure that P/L Ops, Failures Will Not Endanger Crew, Station, Other Payloads (FMEA's, Failure Propagation, Debris Impacts, Etc.)
  - ◊ Physical Integration
    - Perform Required P/L to Rack, Carrier Integration
  - ◊ Payload Operations
    - On-orbit Payload Installation & C/O
    - Conduct Experiment Runs, Gather Data
    - Telescience & On-orbit Control
    - Safing, Deintegration & Return to Developer
  - ◊ Post Flight Debriefing, Lessons Learned, and Data Analysis



## Space Station Freedom User/Payload Integration & Accommodations

Alan C. Holt, Deputy Director (Acting), User Integration Division  
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### Space Station User Integration Process

SPACE STATION FREEDOM  
UTILIZATION & OPERATIONS

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#### User Support Features

- ◊ Standardized Flows for Payload Classes
  - Payloads Integration Flows Optimized for Level of P/L Complexity
  - Streamlined Flows for Rapid Response Research Payloads
    - Payloads Meet Pre-defined Constraints
    - Users of Existing Facilities
- ◊ Payload Accommodations Manager
  - Single Point of Contact Between User/Sponsor & SSP
  - Assists User During All Phases After Selection
- ◊ Science & Technology Centers
  - Conduct Tests, Modelling, Physical Integration for User
  - Both Gov't and Commercial (NASA Approved) Entities
- ◊ Payload Operations
  - Payload Operations Conducted by User (Telescience)
  - Overall Coordination, Safety Monitoring Provided by POIC
  - Distributed User Locations
- ◊ Computer Supported Document Preparation, Reviews
  - Use of Expert Systems as Appropriate ("Smart Documents")

### Space Station User Integration Process

SPACE STATION FREEDOM  
UTILIZATION & OPERATIONS

SCU

#### "Beat The System"

- ◊ TWO PATHS TO SIMPLE INTEGRATION, RAPID FLIGHTS
  - Use an Existing "Facility Class Payload"
    - ¶ Freedom is a Long Duration "Orbital International Research and Development Lab"
      - Analogous to: Argonne National Laboratory, LaRC, Kitt Peak, LeRC, etc.
    - ¶ Major Facilities and Lab Support Equipment Available:
      - Truss Payload Accommodation Equipment, Payload System, Mobile Servicing Center, Flight Telerobotic Servicer, SS Furnace Facility, EVA Servicing, Glovebox, etc.
    - ¶ Use of Existing Facilities Requires Integration of Sample, Procedures: No DDT&E, Certification of Unique Hardware
  - Design/Build an "R<sup>3</sup>" Payload
    - ¶ "R<sup>3</sup>" = Rapid Response Research: Payloads Defined to Established Guidelines (extension of GAS, STS Mid deck):
      - ¶ Simple, Standard Interfaces
      - ¶ Modest Resource Requirements
      - ¶ Standard Req'ts for Safety, Physical Integration, Crew Support
      - ¶ Both Internal and External

# Space Station Freedom User/Payload Integration & Accommodations

Alan C. Holt, Deputy Director (Acting), User Integration Division  
Utilization & Operations Group  
NASA Space Station Freedom Program Office, Reston, Virginia

## Space Station User Integration Process

SPACE STATION FREEDOM  
UTILIZATION & OPERATIONS

SCU

### User/Payload Integration Complexity

Longest Duration  
(2 - 5 Years)



Shortest Duration

- ◊ User Designs/Supplies Facility Class (Multiple User) Payload for Station
- ◊ User Designs/Supplies Standard (Single User) Payload for Station
- ◊ User Modifies Facility P/L Hardware, Software and Operations and Provides Samples, Specimens
- ◊ User Designs/Supplies R<sup>3</sup> Payload
- ◊ User Modifies Existing Facility Payload Software and Operations, Provides Samples
- ◊ User Modifies Facility Operations and Provides Samples, Consumables

Most Complex



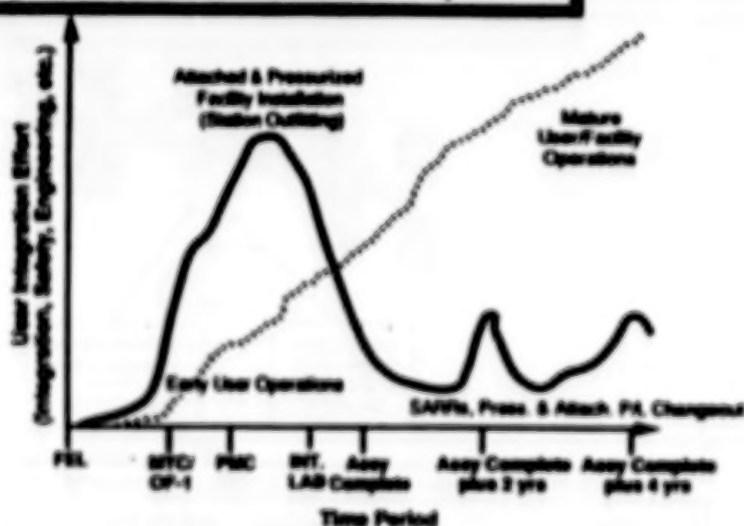
Least Complex

## Space Station User Integration Process

SPACE STATION FREEDOM  
UTILIZATION & OPERATIONS

SCU

### Existing Facilities Use Dominates Mature Operations



— Traditional "Payload/Mission Integration" for hardware being shipped to/from Orbit

..... "Reconfiguration" of on-Orbit Facilities/Payloads to support Multiple User Operations (includes shipments/changeout/use of technology units, specimens, samples and consumables)

**Space Station Freedom User/Payload Integration & Accommodations**

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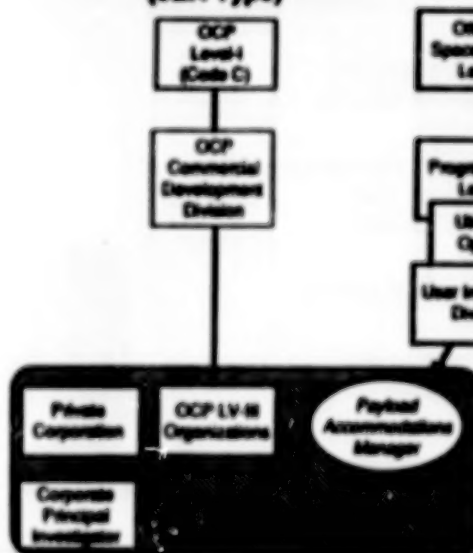
**Space Station User Integration Process**

SPACE STATION FREEDOM  
 UTILIZATION & OPERATIONS

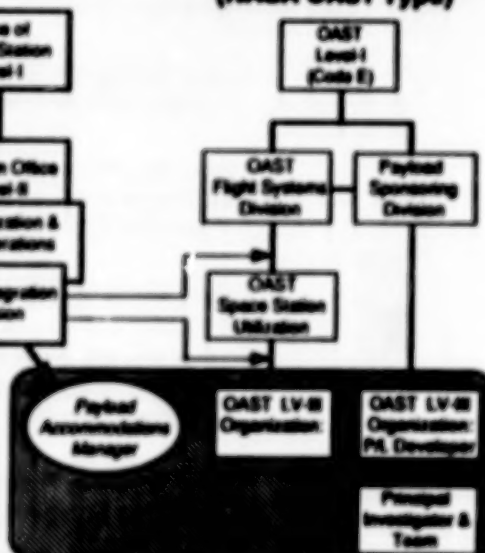
CSU

**Examples of Station-to-User Interface:**  
**U.S. Commercial Cooperative vs. U. S. Technology User**

**Commercial Cooperative (JEA Type)**



**Government Technology (NASA OAST Type)**

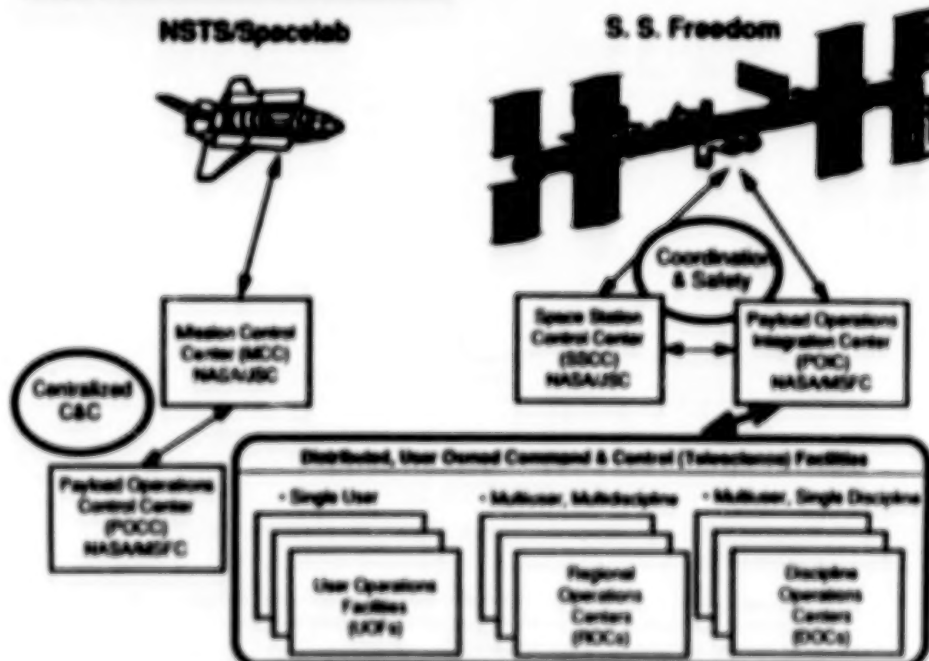


**Space Station User Integration Process**

SPACE STATION FREEDOM  
 UTILIZATION & OPERATIONS

CSU

**User Operations Architecture**



***Space Station Freedom User/Payload Integration & Accommodations***

Alan C. Holt, Deputy Director (Acting), User Integration Division  
Utilization & Operations Group  
NASA Space Station Freedom Program Office, Reston, Virginia

**SPACE STATION FREEDOM  
TECHNOLOGY PAYLOAD ACCOMMODATION**

---

- PROVIDES FOR MULTIPLE TYPES AND SIZES OF TECHNOLOGY R.&D. OPPORTUNITIES
  - QUIET AND ACTIVE ENVIRONMENTAL CONDITION PERIODS CAN BE SCHEDULED
- SPACE STATION FREEDOM, TOGETHER WITH CO-ORBITING PLATFORM TEST FACILITIES, CAN FUNCTION AS A MAJOR TEST BED FACILITY
  - TO SUPPORT INTERPLANETARY SPACECRAFT R.&D.
  - TO SUPPORT LUNAR/MARS BASE TECHNOLOGY AND SYSTEMS R.&D.
- SPACE STATION FREEDOM USER INTEGRATION AND PAYLOAD ACCOMMODATION PROCESSES WILL BE ESTABLISHED
  - TO INSURE RAPID AND SUCCESSFUL INTEGRATION OF TECHNOLOGY PAYLOADS
  - WILL ENABLE "SKUNK WORKS" R.&D. IN SPACE.



**CRITICAL IN-SPACE TECHNOLOGY NEEDS**  
**Space Structures**

Martin Mikulas, Jr.  
Langley Research Center  
Hampton, Virginia

**THEME ELEMENT #1 : STRUCTURES**

1. SYSTEM IDENTIFICATION
  - QUASI-STATIC
  - DYNAMIC
2. VERIFICATION OF PREDICTION METHODS
3. ERECTABLE STRUCTURES CONSTRUCTION
4. PRECISION SENSOR DEVELOPMENT
5. STRUCTURAL INTEGRITY

**THEME ELEMENTS #2 & 3 : CONTROL/STRUCTURE  
INTERACTION & CONTROLS  
(COMBINED)\***

1. FLEXIBLE MULTIBODY/ARTICULATED CONTROL
2. PRECISION POINTING AND SHAPE DIMENSIONAL CONTROL
3. MULTIPLE INTERACTING CONTROL SYSTEM
4. DAMPING AND VIBRATION SUPPRESSION
5. VIBRATION ISOLATION

\*RECOMMENDATIONS: EXPERIMENTS SHOULD BE MULTIDISCIPLINARY IN NATURE  
AND PREFERABLY IN THE FORM OF REUSABLE TEST BEDS.

NOTE: Lists are in priority order, starting with 1 for each Theme Element

**CRITICAL IN-SPACE TECHNOLOGY NEEDS**  
**Space Environmental Effects**

Lubert J. Lager  
Johnson Space Center  
Houston, Texas

**THEME ELEMENT #1 : ATMOSPHERIC EFFECTS AND  
CONTAMINATION**

1. ACTIVE MEASUREMENT OF ATMOSPHERIC CONSTITUENTS SUCH AS ATOMIC OXYGEN, TO SUPPORT STUDIES OF ALL ATMOSPHERIC INTERACTION PHENOMENA
2. GLOW PHENOMENA INFORMATION TO SUPPORT SENSOR DESIGN
3. CONTAMINATION EFFECTS AND ATOMIC OXYGEN EROSION DATA FOR MATERIAL DURABILITY ASSESSMENT FUNCTIONAL PERFORMANCE PREDICTION AND MODEL DEVELOPMENT AND VERIFICATION

**THEME ELEMENT #2 : MICROMETEOROID AND DEBRIS**

1. CHARACTERIZATION OF THE LOW EARTH ORBIT DEBRIS ENVIRONMENT
  - PARTICLE SIZE DISTRIBUTION
  - MORE INFORMATION ON DEBRIS CHARACTERISTICS - SPECTRAL PROPERTIES, SHAPE, COMPOSITION
2. LONG TERM SURFACE DEGRADATION FROM DEBRIS
3. DEVELOP AND VERIFY COLLISION WARNING SYSTEMS TECHNOLOGY
4. EVALUATE AND VERIFY MITIGATION TECHNIQUES

**THEME ELEMENT #3 : CHARGED PARTICLES &  
ELECTROMAGNETIC RADIATION EFFECTS**

1. BETTER CHARACTERIZATION OF RADIATION ENVIRONMENT IN POLAR REGION AND VAN ALLEN RADIATION BELTS & ASSOCIATED WITH SOLAR FLARE ACTIVITY
2. LONG TERM, CONTINUOUS MEASUREMENTS OF MATERIAL PHYSICAL AND ELECTRICAL PROPERTIES IN CRITICAL ORBITS FOR UNDERSTANDING OF INTERACTION MECHANISM AND VALIDATION OF GROUND BASED TESTING
3. DETERMINE THE EFFECTS OF GAS RELEASES IN LEO ON ELECTROMAGNETIC INTERACTIONS
4. DEVELOPMENT OF SIMPLE SMALL AUTONOMOUS SENSORS FOR MEASUREMENT OF SURFACE CHARGING, RADIATION EXPOSURE AND ELECTRIC FIELDS

NOTE: Lists are in priority order, starting with 1 for each Theme Element

**CRITICAL IN-SPACE TECHNOLOGY NEEDS**  
**Power Systems and Thermal Management**

Roy McIntosh  
Goddard Space Flight Center  
Greenbelt, Maryland

**THEME ELEMENT #1 : DYNAMIC AND NUCLEAR POWER SYSTEMS**

1. GAS COLLECTION AND RETENTION IN LIQ COOLANTS
2. FREEZE/THAW IN LIQ METAL SYSTEMS
3. GAS BUBBLE NUCLEATION/GROWTH IN LIQ METALS
4. TWO COMPONENT (SOLID/LIQUID) PUMPING/SEPARATION
5. TWO PHASE LIQ/GAS SEPARATION IN COOLANTS

**THEME ELEMENT #2 : CONVENTIONAL POWER SYSTEMS**

1. ADVANCED ENERGY STORAGE
2. ADVANCED P.V. CELL TECHNOLOGY
3. PRIMARY & REGENERATIVE FUEL CELLS
4. THERMAL ENERGY STORAGE
5. CONTAMINATION, UV & CHARGED PARTICLE PV EFFECTS

**THEME ELEMENT #3 : THERMAL MANAGEMENT**

1. TWO-PHASE HEAT TRANSFER
2. HEAT PIPES (LIQUID METAL & CRYO)
3. CAPILLARY LOOPS
4. TWO-PHASE FLOW & STABILITY
5. VOID BEHAVIOR FLIGHT TEST

**NOTE:** Lists are in priority order, starting with 1 for each Theme Element

**CRITICAL IN-SPACE TECHNOLOGY NEEDS**  
**Fluid Management and Propulsion Systems**

Lynn Anderson  
Lewis Research Center  
Cleveland, Ohio

**THEME ELEMENT #1 : ON-ORBIT FLUID MANAGEMENT**

1. FLUID TRANSFER
2. MASS GAUGING
3. THERMODYNAMIC VENT SYSTEM/MIXING
3. LIQUID ACQUISITION DEVICES
3. FLUID DUMPING/TANK INERTING
4. LIQUID DYNAMICS/SLOSH
5. AUTOGENOUS PRESSURIZATION
5. LONG TERM STORAGE

**THEME ELEMENT #2 : PROPULSION**

1. PLUME IMPACTS & CHARACTERISTICS
2. ELECTRIC PROPULSION SPACE TEST
3. MULTIDISCIPLINE SPACE TEST BED

**THEME ELEMENT #3 : FLUID PHYSICS**

1. LIQUID-VAPOR INTERFACES
2. POOL/FLOW BOILING
2. CONDENSATION/EVAPORATION
3. ADVANCING LIQUID FRONTS
3. BUBBLE/DROPLET DYNAMICS

NOTE: Lists are in priority order, starting with 1 for each Theme Element



**CRITICAL IN-SPACE TECHNOLOGY NEEDS**  
**Automation and Robotics**

Antal K. Bajczy  
Jet Propulsion Laboratory  
Pasadena, California

**THEME ELEMENT #1 : ROBOTIC SYSTEMS**

1. ACTIVE/PASSIVE COMPLIANCE CONTROL AND PRECISION CONTROL IN SMART END EFFECTOR-TOOL-OBJECT INTERACTION
2. DISTURBANCE REJECTION AND STABILIZATION IN ROBOT/PLATFORM COUPLING DYNAMICS
3. SENSOR-CORRECTED PLANNED MOTION EXECUTION, INCLUDING COLLISION DETECTION AND AVOIDANCE
4. ADAPTIVE CONTROL COORDINATION OF MULTIPLE ARM/END EFFECTOR SYSTEMS
5. FAST, HIGH BANDWIDTH AND SMALL VOLUME CONTROL AND DATA PROCESSING ELECTRONICS

**THEME ELEMENT #2 : TELEOPERATIONS**

1. OPERATOR INTERACTION IN MICRO-G WITH FORCE-REFLECTING CONTROL
2. CONTROL TECHNIQUES FOR COMMUNICATION TIME DELAY CONDITIONS
3. OPERATOR MULTI-MODE MANUAL AND SUPERVISORY CONTROL INTERACTION WITH REMOTE MANIPULATORS
4. INTELLIGENT INFORMATION FUSION DISPLAY SYSTEMS
5. OPERATOR PERCEPTIVE/COMMAND INTERACTION WITH HIGH DEGREE OF FREEDOM ARM/END EFFECTOR SYSTEMS

**THEME ELEMENT #3 : ARTIFICIAL INTELLIGENCE**

1. FAULT DETECTION AND PROCESSING SYSTEMS
2. LARGE INPUT/OUTPUT SENSOR AND SENSOR FUSION SYSTEMS
3. INTEGRATED MODEL AND DATA SENSING INFORMATION SYSTEMS
4. CONTINGENCY MANAGEMENT SYSTEMS
5. PARALLEL, INTEGRATED SYMBOLIC AND NUMERIC DATA PROCESSING AND INTELLIGENT OPERATING SYSTEMS

NOTE: Lists are in priority order, starting with 1 for each Theme Element

**CRITICAL IN-SPACE TECHNOLOGY NEEDS**  
**Sensors and Information Systems**

Martin M. Solovick, NASA HQ  
and  
John Dalton, Goddard Space Flight Center

**THEME ELEMENT #1 : SENSORS**

1. SPACE QUALIFIED COOLER AND COOLER SYSTEMS
2. IN SPACE POINTING AND CONTROL

**THEME ELEMENT #2 : COMMUNICATIONS**

1. IN-SPACE LASER COMMUNICATIONS TECHNOLOGY DEMO.

**THEME ELEMENT #3 : INFORMATION SYSTEMS**

1. IN SPACE TESTING/DEMONSTRATION OF HIGHER PERFORMANCE COMPUTERS FOR AUTOMATED OPERATIONS AND ROBOTICS APPLICATIONS
2. IN SPACE TESTING/DEMONSTRATION OF SPECIAL PURPOSE PROCESSORS (e.g., FROM THE CSTI HIGH RATE DATA SYSTEMS PROGRAM) FOR IMAGE COMPRESSION/PROCESSING FOR SCIENCE EXPERIMENTS AND ROBOTICS APPLICATIONS
3. IN SPACE TESTING OF HIGH RATE/VOLUME STORAGE DEVICES FOR IMAGE DATA PROCESSING AND COMMUNICATION LINK BUFFERING
4. IN SPACE TESTING AND CHARACTERIZATION OF RADIATION EFFECTS OF NEXT GENERATION COMMERCIAL AND RADIATION HARDENED DEVICES IN VARIOUS ORBITS FOR GENERAL SPACECRAFT AND INSTRUMENT APPLICATIONS

NOTE: Lists are in priority order, starting with 1 for each Theme Element

**CRITICAL IN-SPACE TECHNOLOGY NEEDS  
In-Space Systems**

Jon B. Hauser  
Marshall Space Flight Center  
Huntsville, Alabama

**THEME ELEMENT #1 : MATERIALS PROCESSING**

1. UNDERSTANDING OF MATERIALS BEHAVIOR IN SPACE ENVIRONMENT
2. DEMONSTRATION OF INNOVATIVE IN-SPACE SAMPLE ANALYSIS TECHNIQUES
2. CHARACTERIZATION AND MANAGEMENT OF THE MICRO-G ENVIRONMENT
3. DEMONSTRATION OF IMPROVED SENSING AND IMAGING TECHNIQUES IN EXPERIMENTAL SYSTEMS
4. DEMONSTRATION OF AUTOMATION AND ROBOTICS APPLICATIONS TO MATERIAL PROCESSING SYSTEMS

**THEME ELEMENT #2 : MAINTENANCE, REPAIR, AND  
FIRE SAFETY**

1. DEMONSTRATION AND VALIDATION OF CAPABILITY TO REPAIR UNEXPECTED EVENTS
1. INVESTIGATION OF LOW-G IGNITION, FLAMMABILITY/FLAME SPREAD AND FLAME CHARACTERISTICS
2. DEMONSTRATION AND VALIDATION OF FLUID REPLENISHMENT TECHNIQUES
2. UNDERSTAND BEHAVIOR OF FLAME EXTINGUISHANTS IN SPACE ENVIRONMENT
3. DEMONSTRATE ROBOTIC MAINTENANCE AND REPAIR CAPABILITY

**THEME ELEMENT #3 : PAYLOAD OPERATIONS**

1. DEMONSTRATION AND VALIDATION OF TELESCIENCE TECHNIQUES
2. DEMONSTRATION OF AUTONOMOUS CHECKOUT, PLACEMENT AND SPACE CONSTRUCTION

NOTE: Lists are in priority order, starting with 1 for each Theme Element

**CRITICAL IN-SPACE TECHNOLOGY NEEDS**  
**Humans In Space**

Ramus Bretol  
Ames Research Center  
San Jose, California

**THEME ELEMENT #1 : EVA / SUIT**

1. TECHNOLOGY FOR MEASUREMENT OF EVA FORCES, MOMENTS, DYNAMICS, PHYSIOLOGICAL WORKLOAD, THERMAL LOADS, AND MUSCULAR FATIGUE
2. EVALUATION OF COOPERATIVE ROLES BETWEEN EVA AND TELEROBOTS AND FOR IVA AND ROBOTICS
3. SUIT CONTAMINANTS DETECTION, IDENTIFICATION AND REMOVAL

**THEME ELEMENT #2 : HUMAN PERFORMANCE**

1. TECHNOLOGY AND MEASUREMENT OF GRAVITY-RELATED ADAPTATION AND RE-ADAPTATION BEHAVIOR
2. TECHNOLOGY FOR IN-SPACE ANTHROPOMETRIC AND PERFORMANCE MEASUREMENT
3. VARIABLE GRAVITY FACILITY AND APPLICATION TECHNOLOGY

**THEME ELEMENT #3 : CLOSED-LOOP LIFE SUPPORT**

1. IMPROVED PHASE SEPARATION SYSTEMS
2. GRAVITY-INDEPENDENT SENSOR SYSTEMS
3. WASTE CONVERSION PROCESSES

NOTE: Lists are in priority order, starting with 1 for each Theme Element



In-Reach

Out-Reach

*In-Reach / Out-Reach Program*

## **In-Reach / Out-Reach Experiments and Experiment Integration Process**

<b>MASTER Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Experiment Descriptions &amp; Experiment Descriptions</b>		<b>Experiment Descriptions</b>
<b>Out-Reach</b>	<b>SPACE STRUCTURES</b> <b><i>In-Space Structural Dynamics: Evaluation of a Skewed Scale Truss</i></b>	<b>Out-Reach</b>
<p align="center"> <b>James H. Peebles</b>          McDonnell Douglas Astronautics, Space Station Division          Contract: NAS1-18688, NASA Langley Research Center, Stanley E. Woodard       </p>		
<p align="center"> <b>EXPERIMENT OBJECTIVE</b> </p> <p>         Define a flight experiment for a hybrid scaled truss in the Orbiter's cargo bay. This experiment may be used to :       </p> <ul style="list-style-type: none"> <li>• Validate analytical techniques for predicting nonlinear dynamic behavior in truss structures</li> <li>• Validate Hybrid Scale theory</li> <li>• Validate 1g ground test techniques</li> <li>• Address other technology issues</li> </ul>		
<p align="center"> <b>BACKGROUND/TECHNOLOGY NEED</b> </p> <ul style="list-style-type: none"> <li>• Many space truss structures envisioned for the future will be too large to dynamically test in full-scale on the ground</li> <li>• Truss joints can dominate dynamic behavior and are not easily scaled due to their complexity</li> <li>• Nonlinear characteristics in joints, such as free play, nonlinear stiffness, damping, and friction can only reasonably be simulated in a 0g space environment</li> <li>• Analytical methods for predicting nonlinear behavior and damping need to be validated</li> <li>•• A hybrid scaled truss with full-size joints and subscale struts offers a smaller, more manageable structure for dynamic testing on the ground and in space. The truss will be used to validate analytic predictive methods, ground test techniques, the hybrid scale concept, and investigate other important technology issues.</li> </ul>		

Out-Reach

SPACE STRUCTURES

Out-Reach

*In-Space Structural Dynamics: Evaluation of a Skewed Scale Truss*

James H. Poulos

McDonnell Douglas Astronautics, Space Station Division

Contract: NAS1-18888, NASA Langley Research Center, Stanley E. Woodard

**EXPERIMENT DESCRIPTION**

- 1g ground test multi-bay erectable truss with short struts and full-size joints (Hybrid Scaled)
- 0g flight test truss and correlate with ground test results
- Validate analytical predictive techniques for nonlinear response and damping
- Investigate other technology issues
  - Instrumentation performance
  - Disturbance propagation
  - Damaged or damped members
  - Utilities/payload integration
  - EVA time lines
  - Long-term exposure test bed

**EXPERIMENT DESCRIPTION**



Out-Reach

SPACE STRUCTURES

Out-Reach

*In-Space Structural Dynamics: Evaluation of a Skewed Scale Truss*

James H. Postles

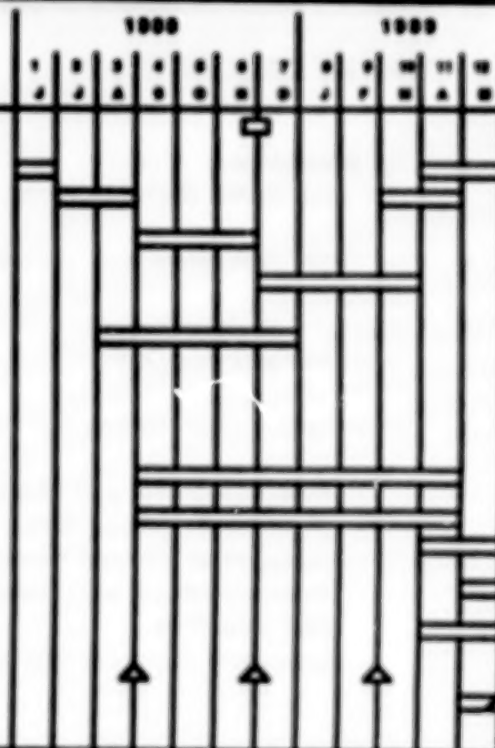
McDonnell Douglas Astronautics, Space Station Division

Contract: NAS1-18688, NASA Langley Research Center, Stanley E. Woodard

**SCHEDULE**

**WORK STATEMENT**

1. Participate in STEP workshop.
2. Develop the specific algorithm.
3. Perform preliminary analysis.
4. Establish methods to avoid tests.
5. Prepare support structure examples:  
 Launch, Ground Test, Ground Test
6. Establish potential test parameters:  
 (a) Wind test  
 (b) Structural joint  
 (c) Strapping  
 (d) Heavy installation  
 (e) Ground test test
7. Develop test plans for in-space and lab tests.
8. Develop an instrumentation plan.
9. Identify requirements for evaluation sources.
10. Develop an analytical modeling plan.
11. Establish an implementation plan.
12. Prepare quarterly progress reports.
13. Prepare and publish final report.





<b>OSTEP Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>		Experiment Descriptions
Out-Reach	<b>Space Structures</b> <b>Middeck 0-Gravity Experiment (MODE)</b>  <b>Prof. Edward F. Crealey and Dr. David W. Miller</b> MIT, Dept. of Aeronautics & Astronautics, Space Engineering Research Center Contract: NAS1-18880, NASA Langley Research Center, Dr. Garrett Homer	Out-Reach
<h2 style="text-align: center;">OBJECTIVES OF MODE</h2> <p>INVESTIGATE DYNAMICS OF TWO ASPECTS OF NONLINEAR SPACECRAFT DYNAMIC SYSTEMS WHICH ARE GRAVITY DEPENDENT</p> <ul style="list-style-type: none"> <li>- <b>MODE I</b>      Dynamics of a partially filled fluid tank as it interacts with flexible vehicle motions. Needed to verify modeling of large mass fraction fluid storage system.</li> <li>- <b>MODE II</b>     Nonlinear contribution of joints of statically indeterminate truss structure to damping and modal structure. Needed to verify structural modeling techniques for use with precision/active structure.</li> </ul>		
<h2 style="text-align: center;">BACKGROUND TO MODE</h2> <p><b>MODE I - FLUID/STRUCTURE INTERACTION</b></p> <ul style="list-style-type: none"> <li>- Linearized and nonlinear fluid models already developed consider large motion of highly curved free surface.</li> <li>- Extensive 1-g testing at M.I.T.</li> <li>- Extensive short term 0-g testing on KC-135.</li> <li>- Twenty seconds of +/- 0.02 g environment not sufficient.</li> </ul> <p><b>MODE II - NONLINEAR TRUSS STRUCTURE</b></p> <ul style="list-style-type: none"> <li>- Linearized and nonlinear models already developed include contribution of material damping and joint nonlinearity</li> <li>- Extensive 1-g and vacuum testing at M.I.T.</li> <li>- Short term 0-g testing in M.I.T. ASTROVAC</li> <li>- Require zero gravity pre-load/long duration to study lightly damped/on-orbit behavior</li> </ul>		

Out-Reach

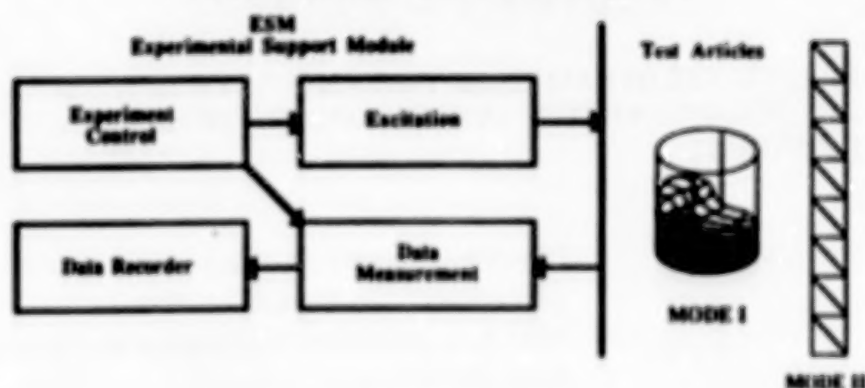
Space Structures

Out-Reach

### Middeck 0-Gravity Experiment (MODE)

Prof. Edward F. Crawley and Dr. David W. Miller  
 MIT, Dept. of Aeronautics & Astronautics, Space Engineering Research Center  
 Contract: NAS1-18890, NASA Langley Research Center, Dr. Garrett Horner

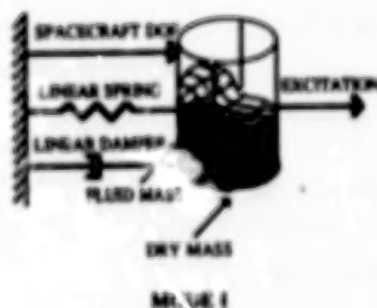
## MIDDECK EXPERIMENT



### EXPERIMENTAL HARDWARE

- ESM: Experimental support module provides capabilities typical of a dynamic test facility in single middeck locker
- Two test articles, MODE I & II, deployed and tested in Middeck.

## TEST ARTICLES



Cylindrical tank  
 coupled to a one DOF  
 dynamic system



Hybrid scale model  
 erectable truss

**INSTEP Workshop**  
**OAST Technology For the Future**  
**Part 1: Executive Summary & Experiment Descriptions**

**Experiment Descriptions**

**Out-Reach**

**Space Structures**

**Out-Reach**

**Middeck 0-Gravity Experiment (MODE)**

**Prof. Edward F. Crawley and Dr. David W. Miller**  
 MIT, Dept. of Aeronautics & Astronautics, Space Engineering Research Center  
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**TIMELINE**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
'88												START
'89					PFER	FER/				CDR		
'90									CREW			
									TRAIN			
'91		PFDR			DE-		FLIGHT					
					LIVER							
'92	FINAL	PMER										
	REPORT											

PFER: Preliminary Flight Experiment Review  
 FER: Flight Experiment Review  
 PFDR: Payload Pre-Delivery Review  
 PMER: Post Mission Experiment Review

**SUMMARY**

- Since each of the phenomena under study is fundamentally influenced by gravity, experiments must be done in zero gravity
- All available Earth based simulations of zero gravity have already been exploited
- These experiments compliment programs of near term interest to NASA.
- Involvement of corporate participants, Boeing Aerospace and McDonnell Douglas, assures relevance of experiment and dissemination of technology

<b>MASTER Workshop</b> <b>CAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>	<b>Experiment Descriptions</b>
<b>Out-Reach</b>	<b>Out-Reach</b>
<p align="center"> <b>SPACE STRUCTURES</b>  <b>Experiment Definition Phase for Measurement and Modeling</b>  <b>of Joint Damping in Space Structures</b>   <b>S.L. Follman and F.J. Redd</b>          Utah State University, Center for Space Engineering          Contract: NAS1-18682, NASA Langley Research Center, Mark Lane       </p>	
<p><u>Experiment Objective</u></p> <p>The objective is to build an experiment which will measure the influence of gravity on structural damping of a truss structure.</p> <ul style="list-style-type: none"> <li>• A three-bay subscale truss will be constructed.</li> <li>• The truss and the joints used will be similar to those proposed for the Space Station.</li> <li>• Ground-based testing will measure damping with 1-g loads.</li> <li>• Fly as Get Away Special experiment to get micro-gravity damping.</li> <li>• Results will provide qualitative data on the influence of gravity on damping.</li> </ul>	
<p><u>Background/Technology Need</u></p> <p>Predicting the amount of damping expected in large space structures is expected to be difficult.</p> <ul style="list-style-type: none"> <li>• Joints holding the structure together will produce some damping.</li> <li>• The amount of damping produced by joints is dependent on several variables.</li> <li>• Damping can be gravity dependent in a truss with pinned joints.</li> <li>• On-ground damping measurements may be in error due to gravity loads.</li> <li>• A data base of in-orbit and on-ground tests is needed to permit better predictions of damping for other structures.</li> </ul>	



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## SPACE STRUCTURES

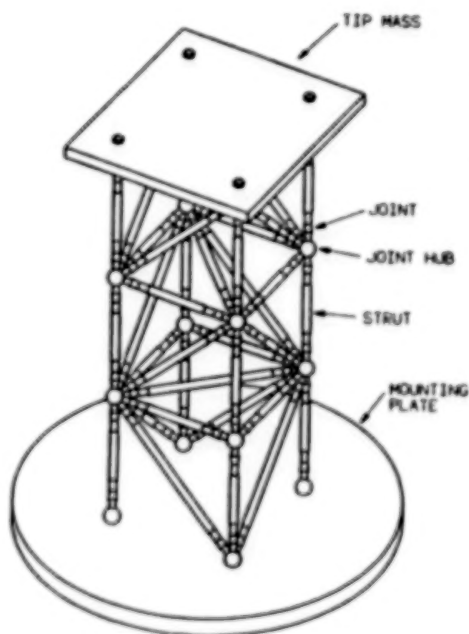
Out-Reach

### Experiment Definition Phase for Measurement and Modeling of Joint Damping in Space Structures

S.L. Folkman and F.J. Redd

Utah State University, Center for Space Engineering

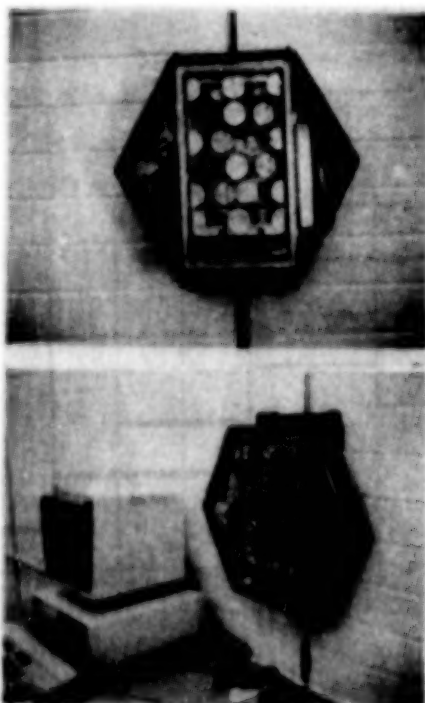
Contract: NAS1-18682, NASA Langley Research Center, Mark Lake



#### Experiment Description

The experiment consists of a three-bay truss and associated hardware for truss excitation and measurement of oscillations.

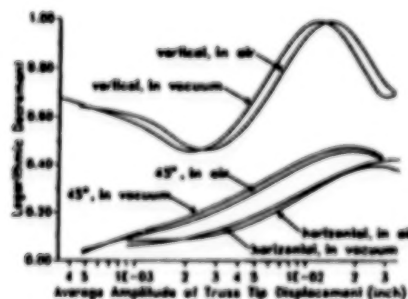
- The experiment fits inside a 5 cubic foot Get Away Special Canister.
- Cantilevered truss with a tip mass to reduce the resonant frequency.
- Canister vented to space to eliminate air damping.
- Truss excitation will induce bending modes in two directions or a torsional mode.
- Means for tip mass support during launch and reentry will be provided.



#### Previous Experiments

An experiment has been constructed to measure damping of a tetrahedral truss with pinned joints.

- One of 6 experiments to fly as a GAS Payload.
- Very small project budget.
- Damping is gravity dependent



Out-Reach

## SPACE STRUCTURES

Out-Reach

### Experiment Definition Phase for Measurement and Modeling of Joint Damping in Space Structures

S.L. Folkman and F.J. Redd

Utah State University, Center for Space Engineering  
Contract: NAS1-18682, NASA Langley Research Center, Mark Lake

#### Prototype truss design

As part of the Experiment Definition Phase we are constructing a truss for ground testing.



- 3 Bay truss.
- First bay uses 1/4 scale joints made by Star•Net Structures.
- An inexpensive bolted joint is used elsewhere.
- Ground tests will examine the influence of gravity on damping.

#### 1988-89 Schedule

	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Joint Selection												
Truss Design												
Excit./Locker Design												
Prototype Design												
Fabricate Prototype												
Ground Testing												
Drawing Package												
Report Preparation												

INSTEP Workshop OAST Technology For the Future Part 1: Executive Summary & Experiment Descriptions		Experiment Descriptions
Out-Reach	<b>SPACE STRUCTURES</b> <i>Payload Vibration Isolation in Microgravity Environment</i>	Out-Reach
Carl H. Gerhold and Richard M. Alexander Texas A&M University, Mechanical Engineering Department Contract: NAS9-17972, Johnson Space Center, A.R. Rocha, Loads & Dynamics Branch		
 <b><u>EXPERIMENT OBJECTIVE:</u></b>  <ul style="list-style-type: none"><li>• <b>Develop both passive and active techniques to isolate sensitive payloads from shock and vibration.</b></li><li>• <b>Demonstrate candidate methodologies in low-gravity simulator.</b></li></ul>		

**BACKGROUND/TECHNOLOGY NEED**

Experiments and processes in laboratory module require microgravity. Vibration excited by adjacent experiments or crew activity can contaminate the low-gravity environment and degrade the usefulness of the experiment or process.

- **Study will identify vibration isolation techniques for rigid body payload.**
- **Can verify methodology concept in one-"g" environment.**
- **Working model design verification requires shuttle flight.**

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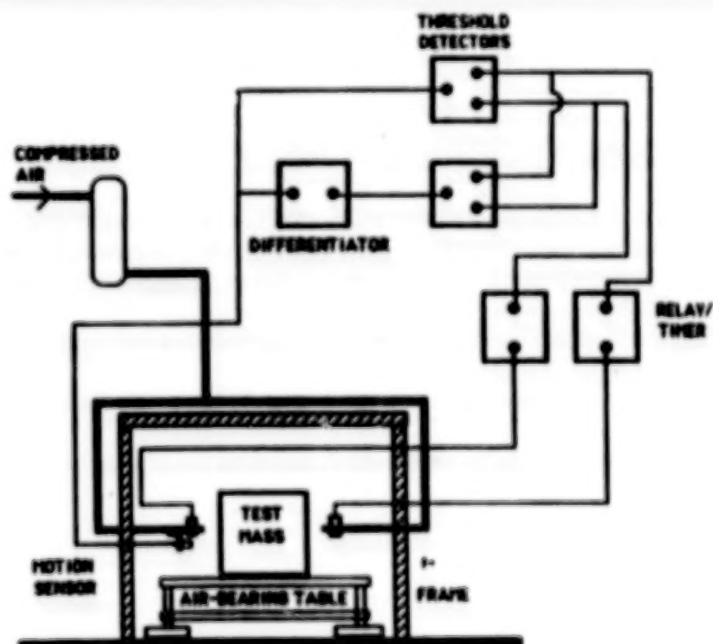
**SPACE STRUCTURES**  
*Payload Vibration Isolation in Microgravity Environment*

Out-Reach

Carl H. Gerhold and Richard M. Alexander  
Texas A&M University, Mechanical Engineering Department  
Contract: NASA-17972, Johnson Space Center, A.R. Rocha, Loads & Dynamics Branch

**EXPERIMENT DESCRIPTION:**

- Low-gravity is simulated in the horizontal plane with a cart supported on air-bearing pads.
  - The cart rides on a film of air above a smooth, flat marble surface.
  - Motion of the test payload is measured using an ultrasonic sensor.
- Candidate isolation techniques are evaluated in terms of transmission ratio for harmonic and impulsive excitations.
  - Passive Isolation
    - Utilize existing theory
    - Design for isolation = 99.9975%
  - Active Method
    - Payload floats in enclosure
    - Control system keeps payload centered



Air Jet Controller System Experiment Set-up



Out-Reach

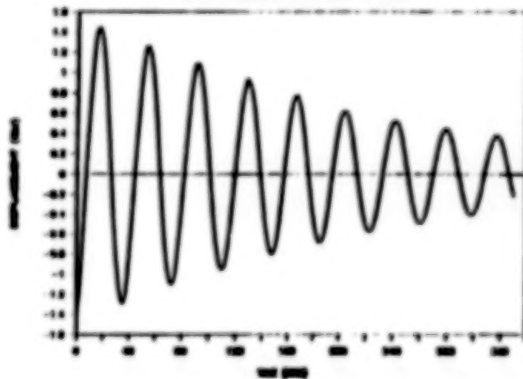
# SPACE STRUCTURES

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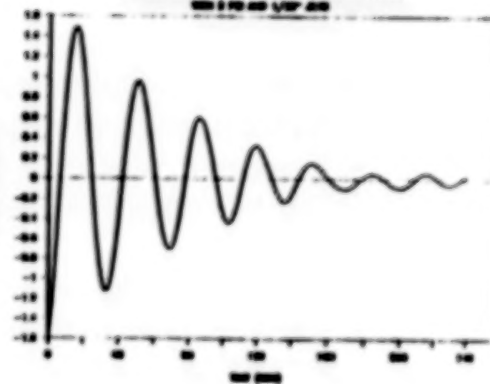
## Payload Vibration Isolation in Microgravity Environment

Carl H. Gerhold and Richard M. Alexander  
Texas A&M University, Mechanical Engineering Department  
Contract: NAS9-17972, Johnson Space Center, A.R. Rocha, Loads & Dynamics Branch

FREE VIBRATION OF CART

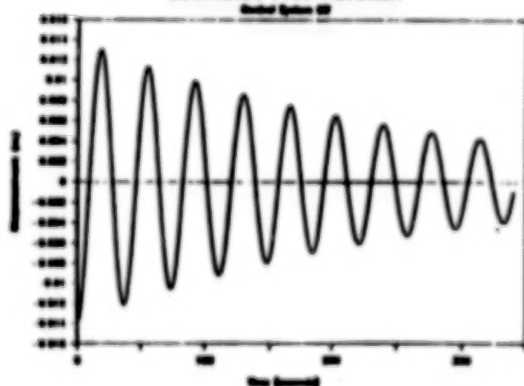


CONTROLLED CART VIBRATION

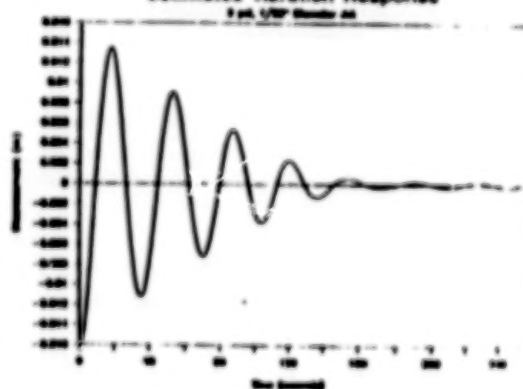


MEASURED VIBRATION RESPONSE

Estimated Free Vibration



Estimated Vibration Response



RESPONSE ESTIMATED BY ANALYTICAL MODEL

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<div style="text-align: center; margin-bottom: 20px;"> <b><u>CONCLUSIONS:</u></b> </div> <ul style="list-style-type: none"> <li>• <b>Vibration control demonstrated</b> <ul style="list-style-type: none"> <li>• <b>System has one degree of freedom</b></li> <li>• <b>Passive system can meet impulse criterion</b></li> <li>• <b>Digital controller developed for active system</b></li> </ul> </li> <li>• <b>Analytical model developed</b> <ul style="list-style-type: none"> <li>• <b>Verified by experiment</b></li> <li>• <b>Will be used to develop control system parameters</b></li> </ul> </li> </ul>																																																																								
<div style="text-align: center; margin-bottom: 20px;"> <b><u>SCHEDULE</u></b> </div> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td style="width: 10%; text-align: center;">'88</td> <td style="width: 10%;"></td> <td style="width: 10%; text-align: center;">'89</td> <td style="width: 20%;"></td> </tr> <tr> <td style="text-align: left;">I. Background</td> <td></td> <td></td> <td></td> <td style="text-align: center;">J J A S O N D J F M A M</td> </tr> <tr> <td style="text-align: left;">A. Develop/Refine Isolation Criteria</td> <td colspan="4" style="border-bottom: 1px solid black;"></td> </tr> <tr> <td style="text-align: left;">II. Passive Methods</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: left;">A. Select Candidate Techniques</td> <td colspan="4" style="border-bottom: 1px solid black;"></td> </tr> <tr> <td style="text-align: left;">B. Develop Design Parameters</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: left;">C. Fabricate Samples &amp; Evaluate</td> <td></td> <td></td> <td></td> <td style="border-bottom: 1px solid black;"></td> </tr> <tr> <td style="text-align: left;">III. Active Methods</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: left;">A. Select Candidate Technique</td> <td></td> <td></td> <td></td> <td style="border-bottom: 1px solid black;"></td> </tr> <tr> <td style="text-align: left;">B. Develop Design Parameters</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: left;">C. Fabricate and Test</td> <td></td> <td></td> <td></td> <td style="border-bottom: 1px solid black;"></td> </tr> <tr> <td style="text-align: left;">IV. Experiment Facility</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: left;">A. Fabricate 1 DOF System</td> <td></td> <td></td> <td></td> <td style="border-bottom: 1px solid black;"></td> </tr> <tr> <td style="text-align: left;">B. Modify for Plane Motion</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>				'88		'89		I. Background				J J A S O N D J F M A M	A. Develop/Refine Isolation Criteria					II. Passive Methods					A. Select Candidate Techniques					B. Develop Design Parameters					C. Fabricate Samples & Evaluate					III. Active Methods					A. Select Candidate Technique					B. Develop Design Parameters					C. Fabricate and Test					IV. Experiment Facility					A. Fabricate 1 DOF System					B. Modify for Plane Motion				
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Out-Reach

**SPACE STRUCTURES**  
*Generic Pointing Mount*

Out-Reach

Robert W. Bosley  
Allied-Signal Aerospace Co., Aeresearch Los Angeles Division  
Contract: NAS1-18885, Langley Research Center, Sharon S. LaFleur

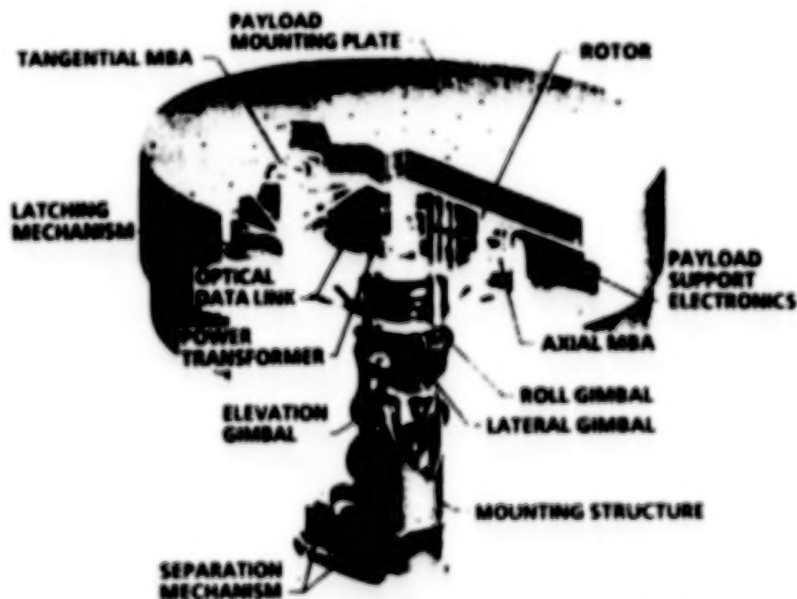
**EXPERIMENTAL OBJECTIVE**

**CHARACTERIZE THE PERFORMANCE CAPABILITIES OF A GENERIC POINTING MOUNT DESIGNED TO ISOLATE VIBRATION AND AIM INTERCHANGEABLE PAYLOADS OVER LARGE ARTICULATION ANGLES.**

**THIS EXPERIMENT WILL:**

- **VERIFY THE ABILITY OF ADVANCED MAGNETIC SUSPENSIONS TO:**
  - **ELIMINATE THE NEED FOR MECHANICAL GIMBALS**
  - **OPERATE OVER LARGE ARTICULATION ANGLES**
  - **IMPLEMENT ADAPTIVE CONTROL LAWS**
  - **UTILIZE ARTIFICIAL INTELLIGENCE SCHEMES**
- **ESTABLISH DESIGN/PERFORMANCE DATA BASE FOR THE NEXT GENERATION OF GENERIC POINTING MOUNTS**

**CURRENT SPACE DEPLOYABLE POINTING TECHNOLOGY**



**SPERRY/NASA ANNULAR SUSPENSION AND POINTING SYSTEM (ASPS)**

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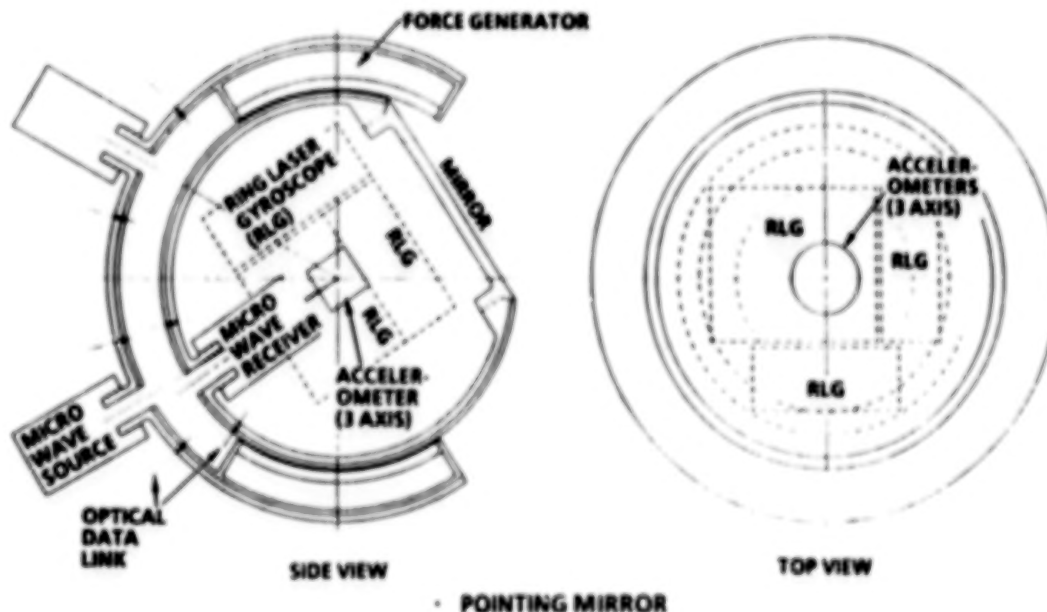
# SPACE STRUCTURES Generic Pointing Mount

Out-Reach

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## **TECHNOLOGIES/FEATURES USED BY THE GENERIC POINTING MOUNT:**

- UTILIZES ADVANCED MAGNETIC SUSPENSION/BEARING TECHNOLOGY IN LIEU OF MECHANICAL GIMBALS FOR ARTICULATION
- AUTOMATICALLY MEASURES THE MASS, MOMENTS OF INERTIA, RESONANT FREQUENCIES, RESONANT MODE SHAPES, AND VIBRATION DAMPING REQUIREMENTS OF EACH PAYLOAD
- AUTOMATICALLY OPTIMIZES THE MAGNETIC SUSPENSION AND POINTING/TRACKING SERVOSYSTEM CONTROL LAWS TO MATCH EACH PAYLOAD
- OPTIMIZES THE CONTROL LAWS IN REAL TIME FOR SIMULTANEOUS CONVERGENCE OF POSITION, VELOCITY, AND ACCELERATION ERRORS
- TRANSFERS POWER AND DATA ACROSS THE MAGNETIC SUSPENSION GAP WHILE EXPERIENCING LARGE ARTICULATION ANGLES



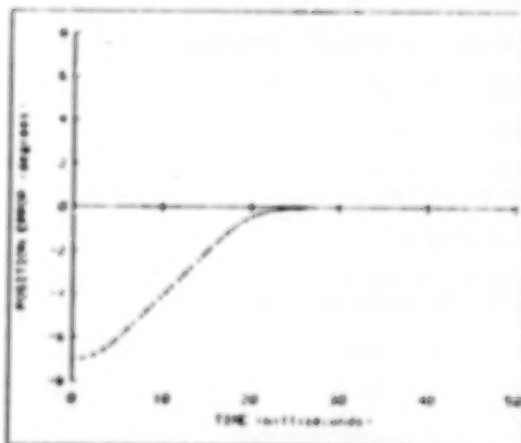


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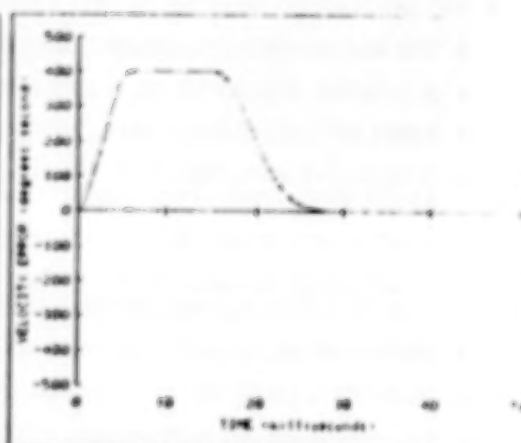
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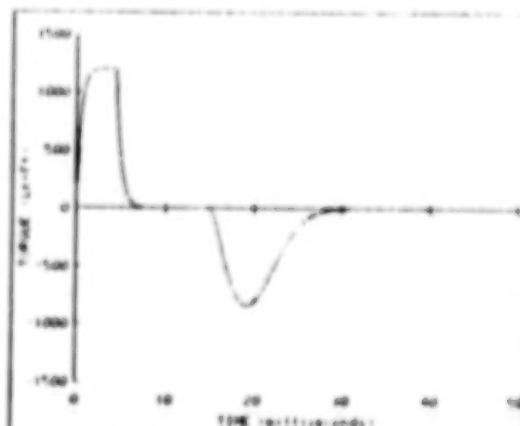


TARGET PERFORMANCE OF INERTIALLY SUPPLEMENTED TEST AXIS  
 TORQUE LIMITED TO 10000 LB-FT  
 WEIGHT OF MOUNT IS 100 POUNDS  
 ARTICULATION CAPABILITY IS PLUS OR MINUS 2 DEGREES  
 NO LOAD TORQUE (NOT FORCE GENERATION) CAN BE USED TO 1000 LB-FT  
 NO LOAD RATE OF CHANGE OF TORQUE IS 1,000,000 LB-FT/SEC  
 NO LOAD VELOCITY LIMIT IS SET AT 100 DEGREES PER SECOND

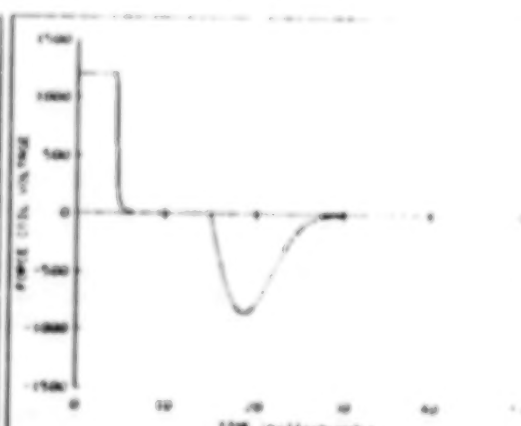


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SIX ORDERS OF MAGNITUDE ERROR REDUCTION WITH NO OVERSHOOT/UNDERSHOOT



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<b>ISTEP Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>	<b>Experiment Descriptions</b>
<b>Out-Reach</b>	<b>Out-Reach</b>
<div data-bbox="695 232 1001 304" data-label="Section-Header"> <p align="center"><b>SPACE STRUCTURES</b> <b>Generic Pointing Mount</b></p> </div> <div data-bbox="510 338 1194 427" data-label="Text"> <p align="center">Robert W. Bosley  Allied-Signal Aerospace Co., Aeresearch Los Angeles Division  Contract: NAS1-18685, Langley Research Center, Sharon S. LaFleur</p> </div> <div data-bbox="329 506 628 535" data-label="Section-Header"> <p><b>EXPERIMENT DESCRIPTION:</b></p> </div> <div data-bbox="354 546 1367 1783" data-label="List-Group"> <ul style="list-style-type: none"> <li>• THE SPACE BASED POINTING MOUNT MODULE WILL BE COMPRISED OF: <ul style="list-style-type: none"> <li>• THE MAGNETICALLY SUSPENDED AND CONTROLLED GENERIC POINTING MOUNT</li> <li>• A POINTING MIRROR ATTACHED TO AND ARTICULATED BY THE MOUNT</li> <li>• THREE OPTICAL AUTOCOLLIMATORS (one articulated)</li> <li>• A TELESCOPE WITH STAR PATTERN RECOGNITION CAPABILITIES AND STAR POSITION/POINTING ERROR SENSORS. THIS TELESCOPE WILL BE ALTERNATELY <ul style="list-style-type: none"> <li>- ATTACHED TO AND ARTICULATED BY THE POINTING MOUNT.</li> <li>- ATTACHED TO A NON-ARTICULATED SURFACE IN THE MODULE SO AS TO RECEIVE OPTICAL SIGNALS/IMAGES REFLECTING OFF THE POINTING MIRROR</li> </ul> </li> <li>• SIMULATED INSTRUMENTS/DEVICES WITH DIFFERENT MECHANICAL IMPEDANCES</li> <li>• AN INERTIAL MEASUREMENT UNIT (IMU) WITHIN THE ARTICULATED POINTING MOUNT</li> <li>• AN IMU WITHIN THE NON-ARTICULATED PORTION OF THE MODULE</li> <li>• POWER AND DATA LINKS BETWEEN THE MOUNTED TELESCOPE AND THE MODULE (across the magnetic suspension gap)</li> <li>• DATA LINKS: <ul style="list-style-type: none"> <li>- TO THE SPACECRAFT IMU AND COMPUTERS</li> <li>- TO ONE OR MORE GROUND STATIONS</li> </ul> </li> </ul> </li> <li>• THE EXPERIMENT WILL BE DIVIDED INTO FIVE SUB-EXPERIMENTS <ul style="list-style-type: none"> <li>SUB-EXPERIMENT 1: CHARACTERIZE THE DYNAMIC SYSTEM PERFORMANCE WHEN SHIFTING LOCK FROM ONE AUTOCOLLIMATOR TO ANOTHER</li> <li>SUB-EXPERIMENT 2: CHARACTERIZE THE ABILITY OF THE SYSTEM TO ADAPT TO CHANGES IN THE MECHANICAL IMPEDANCES OF THE INSTRUMENTS/DEVICES BEING AIMED</li> <li>SUB-EXPERIMENT 3: CHARACTERIZE THE TRACKING STABILITY WHEN THE TELESCOPE IS ARTICULATED AND LOCKED TO A STAR OR EARTH STATION</li> <li>SUB-EXPERIMENT 4: CHARACTERIZE THE TRACKING STABILITY WHEN THE MIRROR/TELESCOPE IS LOCKED TO A STAR OR EARTH STATION AND THE UNARTICULATED TELESCOPE IS EXCITED BY EXTERNAL VIBRATIONS</li> <li>SUB-EXPERIMENT 5: CHARACTERIZE THE TRACKING STABILITY WHEN THE MIRROR IS RELAYING LASER BEAMS GENERATED BY EARTH STATIONS</li> </ul> </li> </ul> </div>	

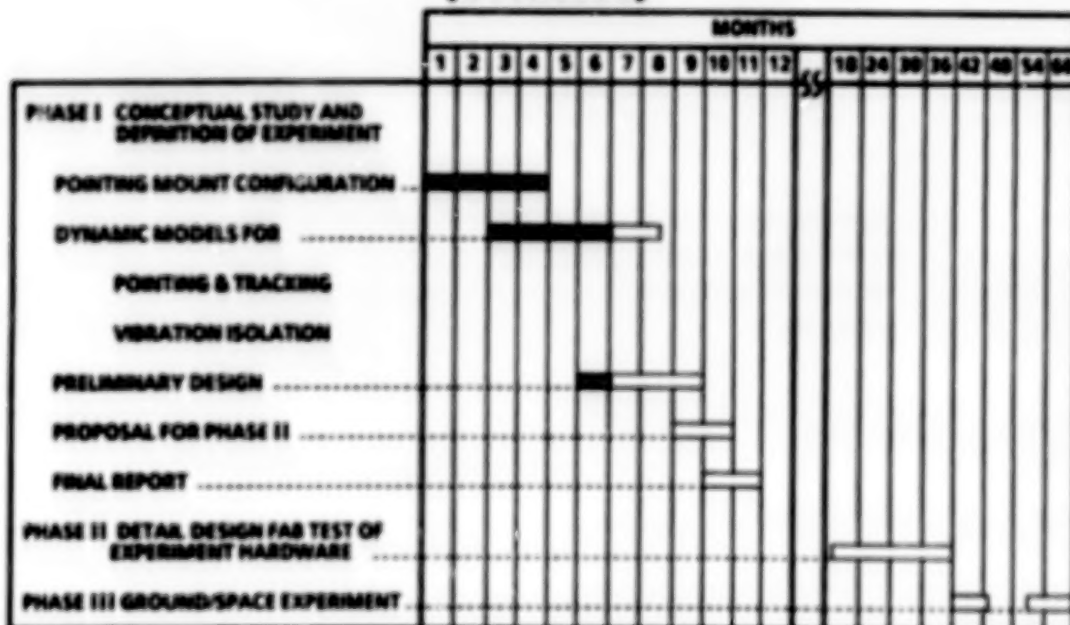
Out-Reach

# SPACE STRUCTURES Generic Pointing Mount

Out-Reach

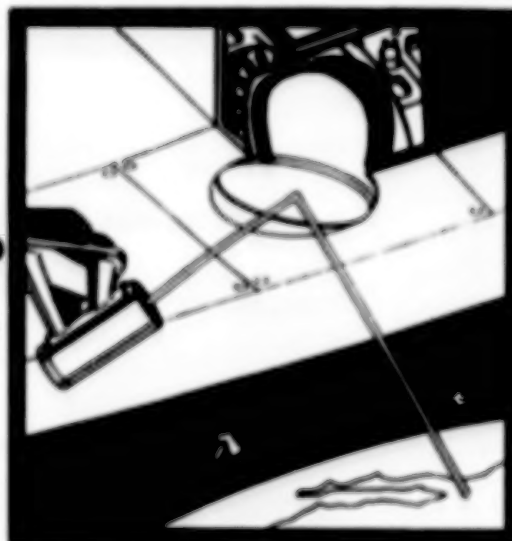
Robert W. Bosley  
Allied-Signal Aerospace Co., Aeresearch Los Angeles Division  
Contract: NAS1-18885, Langley Research Center, Sharon S. LaFleur

## MASTER SCHEDULE (3 PHASES)



### SUMMARY OF EXPERIMENT FEATURES:

- GENERIC POINTING MOUNT FOR INTERCHANGEABLE PAYLOADS
- SYSTEM AUTOMATICALLY ADAPTS CONTROL LAWS TO EACH PAYLOAD
- POINTING CONTROL IN THREE AXES AROUND A SINGLE PIVOT POINT
- 135° ARTICULATION ANGLES



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## SPACE STRUCTURES

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### Space Station Structural Characterization Experiment

James W. Johnson and Paul A. Cooper  
NASA Langley Research Center

## OBJECTIVE

THE DEVELOPMENT OF MODELING TECHNIQUES  
FOR LARGE SPACE STRUCTURES USING ON-ORBIT  
MEASUREMENTS OF SPACE STATION STRUCTURAL  
DYNAMICS

## TECHNOLOGY REQUIREMENT

### LARGE SPACE STRUCTURES

- CANNOT BE INTEGRATED AND TESTED IN 1G
- REQUIRE ANALYTICAL PREDICTION AND / OR ON-ORBIT MEASUREMENT OF PERFORMANCE

DYNAMICS: MODELING TO PREDICT PERFORMANCE

CONTROL: ON-ORBIT CHARACTERIZATION FOR ACTIVE CONTROL



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# SPACE STRUCTURES Space Station Structural Characterization Experiment

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James W. Johnson and Paul A. Cooper  
 NASA Langley Research Center

## EXPERIMENT DESCRIPTION

### o SPACE STATION FREEDOM

- PRESENTS AN EARLY OPPORTUNITY TO DEVELOP MODELING TECHNOLOGY
- MAGNIFIES THE OPPORTUNITY WITH MULTIPLE ASSEMBLY CONFIGURATIONS

### o FLIGHT EXPERIMENT CONCEPT

#### PHASE A

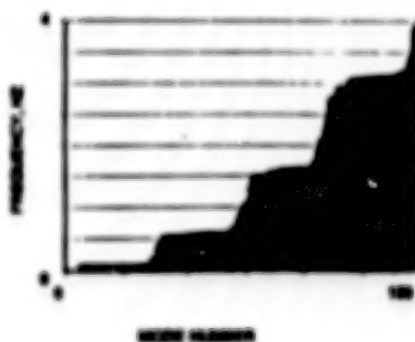
- MODAL TESTING OF SELECTED CONFIGURATIONS THRU ASSEMBLY COMPLETE
  - EXCITATION REBOOST TRANSIENTS  
MODULATED REBOOST
  - MEASUREMENTS ACCELERATION
  - MODAL IDENTIFICATION FREE DECAY

## EXPERIMENT DESCRIPTION

(Cont.)

MODAL DENSITY  
 ASSEMBLY 1 COMPLETE CONFIGURATION

100 HZ / 0.1 Hz



EXCITATION FUNCTIONS  
 STANDBY X RCS JETS

REBOOST TRANSIENTS



MODULATED REBOOST



TIME →

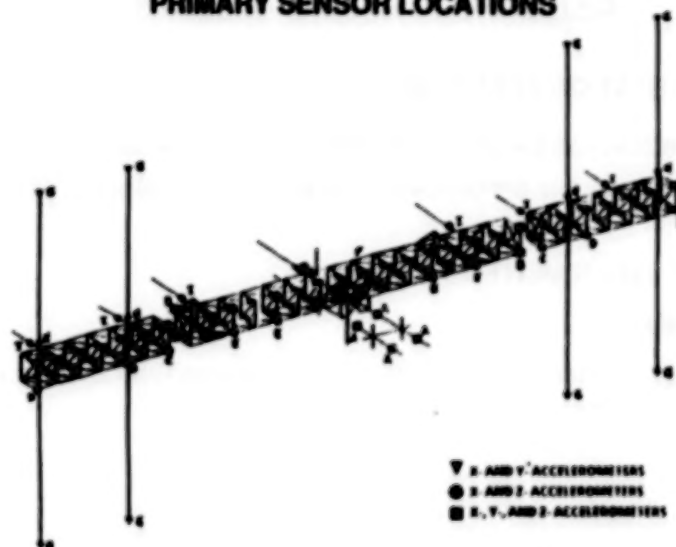
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# SPACE STRUCTURES Space Station Structural Characterization Experiment

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James W. Johnson and Paul A. Cooper  
 NASA Langley Research Center

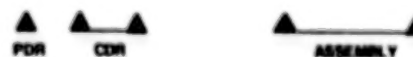
## PRIMARY SENSOR LOCATIONS



## SCHEDULE

CY	88	89	90	91	92	93	94	95	96	97	98
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SPACE STATION FREEDOM



SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT

PHASE A STUDY



PHASE B STUDIES



DESIGN, DEVELOPMENT AND INTEGRATION



FLIGHT EXPERIMENTS



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## SPACE STRUCTURES

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### *Inflatable Solar Concentrator Experiment Definition Program*

Costa Casapelle and Geoff Williams  
L'Garde, Inc.

Contract: NAS1-18881, Langley Research Center, Tom Campbell

#### STUDY OBJECTIVE

ASSESS IN-SPACE THE TWO MOST CRITICAL ISSUES PERTAINING  
TO THE PERFORMANCE OF INFLATABLE STRUCTURES IN SPACE:

- \* ASSESS THE EFFECTS OF SPACE ENVIRONMENT  
ON THE STRUCTURAL INTEGRITY AND SERVICE LIFE:
  - METEORIODS
  - UV RADIATION
  - ATOMIC OXYGEN
- \* DEMONSTRATE THAT INFLATABLE SYSTEMS  
CAN BE DESIGNED TO PROVIDE HIGH LEVELS  
OF STRUCTURAL DAMPING.
  - BYPRODUCT: VALIDATION OF EXISTING  
ANALYTICAL TOOLS THAT  
PREDICT STRUCTURAL DAMPING.

#### BACKGROUND / TECHNOLOGY NEED

- \* INFLATABLE STRUCTURES IN SPACE HAVE BEEN VERY SUCCESSFUL  
AND THEIR ADVANTAGES HAVE BEEN DEMONSTRATED IN SHORT MISSIONS
  - SMALL PACKAGED VOLUMES
  - LOW WEIGHT
  - LESS EXPENSIVE TO BUILD AND TEST THAN COMPETING  
MECHANICALLY ERECTED SYSTEMS
- \* FOR LONG TERM SPACE MISSIONS, AS IN THE CASE OF ANTENNAS  
AND SOLAR CONCENTRATORS, IT IS NECESSARY TO DEMONSTRATE THAT:
  - INDUCED DAMAGE DUE TO ENVIRONMENT (METEORIODS,  
UV RADIATION AND ATOMIC OXYGEN AT LOW EARTH ORBITS)  
CAN BE HANDLED BY ON-BOARD GAS SUPPLY, AND/OR OTHER  
MEANS.
  - INDUCED DYNAMICS ARE DAMPED OUT QUICKLY, SO THAT  
STRUCTURAL ACCURACY IS MAINTAINED.
- \* THIS EXPERIMENT MUST BE CONDUCTED IN-SPACE, BECAUSE  
ZERO GRAVITY, VACUUM, METEORIODS, UV AND ATOMIC OXYGEN  
ARE ALL SIMULTANEOUSLY PRESENT.

<b>INSTEP Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>	<b>Experiment Descriptions</b>
<b>Out-Reach</b>	<div data-bbox="477 232 1189 309" data-label="Section-Header"> <p align="center"><b>SPACE STRUCTURES</b>  <b>Inflatable Solar Concentrator Experiment Definition Program</b></p> </div> <div data-bbox="510 340 1149 434" data-label="Text"> <p align="center">Costa Casanovis and Geoff Williams  L'Garde, Inc.  Contract: NAS1-18681, Langley Research Center, Tom Campbell</p> </div>
<div data-bbox="661 546 997 582" data-label="Section-Header"> <p align="center"><b><u>STUDY DESCRIPTION</u></b></p> </div> <div data-bbox="477 654 1233 1935" data-label="List-Group"> <ol style="list-style-type: none"> <li>1. Trade Studies Will Be Conducted on the: <ul style="list-style-type: none"> <li>• <b>Desirable Orbit Type</b>  Low Earth Orbit (LEO)  High Earth Orbit (HEO)</li> <li>• <b>Inflatable Structure</b>  Type - (e.g., spherical or paraboloid)  Materials - (e.g., kapton, mylar, teflon, etc)  Response Instrumentation (meteoroids, UV, O)  Dynamics Instrumentation  (e.g., accelerometers and/or video)</li> <li>• <b>Carrier Vehicle</b>  Type -  Free Flyer, Nonretrievable  Free Flyer, Retrievable  Space Station   Telemetry -  May not be required for  space station measurements   Control -  Attitude Control?  On-board Microprocessor Type  Inflation Feedback Loop  Inflatable Dynamics Induction Type   Power -  Requirements  Type</li> </ul> </li> <li>2. Recommendations will be made for the most cost effective experimental configuration concept.</li> </ol> </div>	

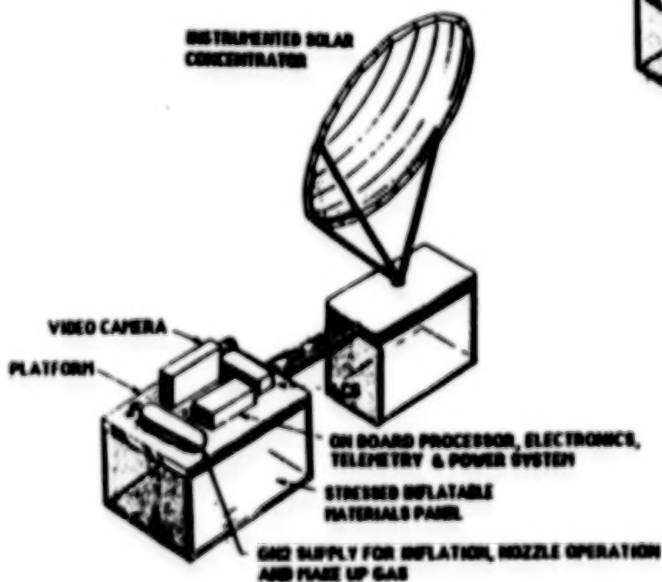
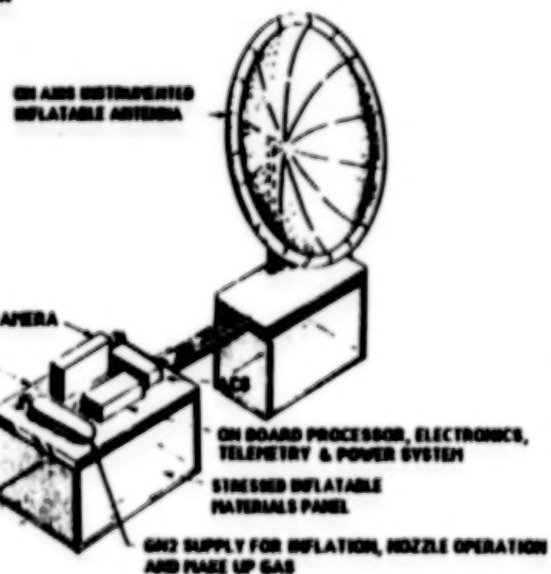
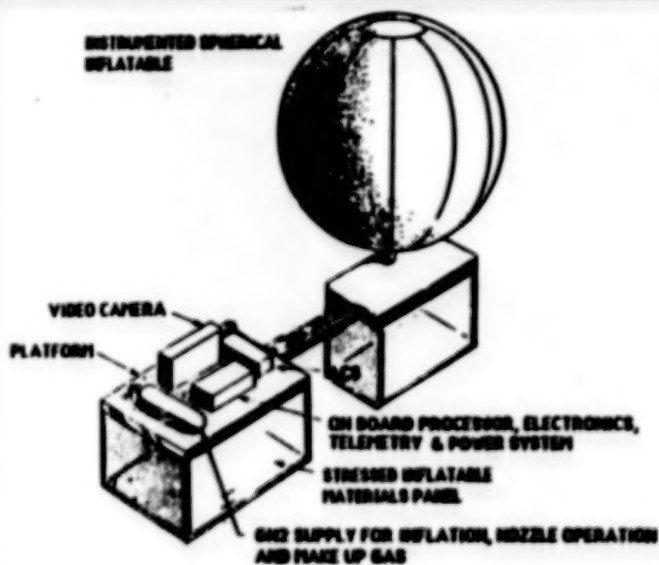


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**SPACE STRUCTURES**  
*Inflatable Solar Concentrator Experiment Definition Program*

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Costa Casapelle and Geoff Williams  
 L'Garde, Inc.  
 Contract: NAS1-18881, Langley Research Center, Tom Campbell

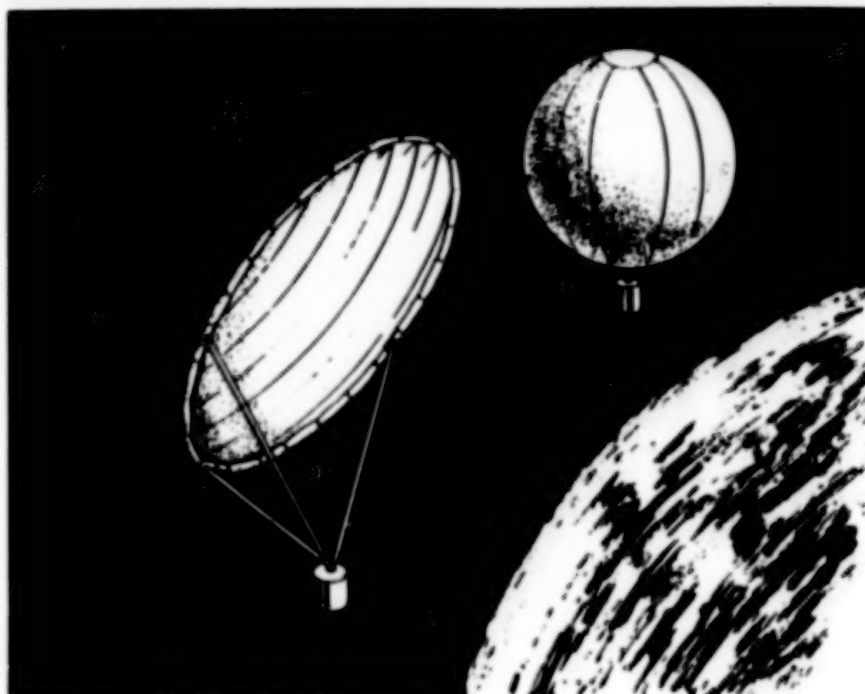


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**SPACE STRUCTURES**  
**Inflatable Solar Concentrator Experiment Definition Program**

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Costa Casaspide and Geoff Williams  
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PROJECTED EXPERIMENT SCHEDULE  
Issue Date 10/24/88



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**SPACE ENVIRONMENTAL EFFECTS**

Out-Reach

Atmospheric Effects and Contamination

***Measurement of Surface Reactions In the Space Environment***

L.R. Magill

Globesat, Inc.

Contract: NAS1-18884, Langley Research Center / JPL, Lenwood G. Clark / Dr. David A. Brinza

**Experiment objectives**

Measure in space effective reaction

rates for degradation of materials

- Selected space materials
- In-space analysis
- Inexpensive, small satellite

**Background**

- Observations of returned specimens indicate severe degradation
- Future structures will make use of composite materials
- Laboratory sources of Sev atomic oxygen are difficult to obtain

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SPACE ENVIRONMENTAL EFFECTS

Out-Reach

Atmospheric Effects and Contamination

*Measurement of Surface Reactions in the Space Environment*

L.R. Magill

Globosat, Inc.

Contract: NAS1-18684, Langley Research Center / JPL, Lenwood G. Clark / Dr. David A. Brinza

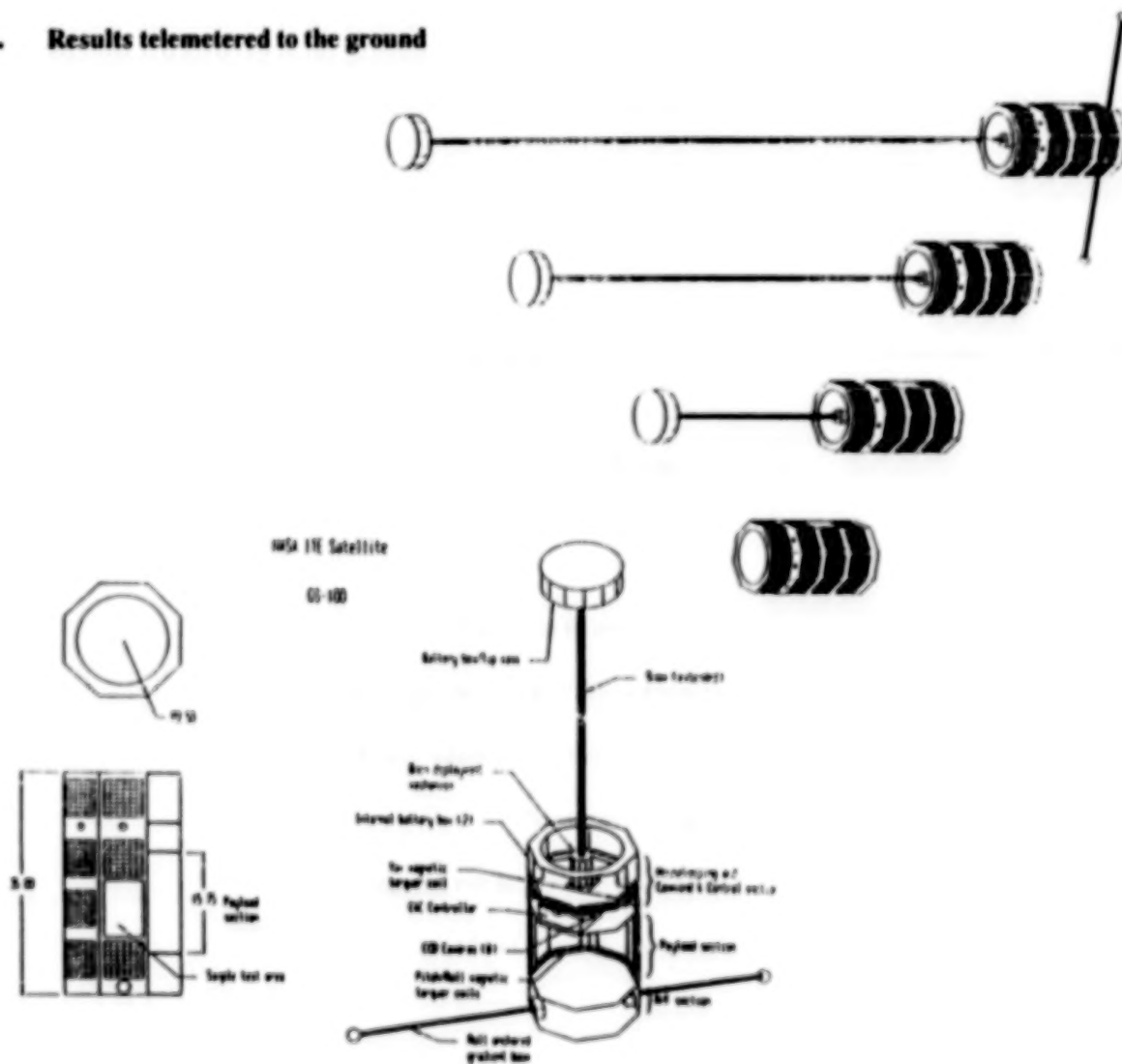
- Gravity Gradient/Magnetic Torque

Stabilized satellite

- Several in-space measurements

to be used

- Results telemetered to the ground





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**SPACE ENVIRONMENTAL EFFECTS**

Out-Reach

Atmospheric Effects and Contamination

***Measurement of Surface Reactions in the Space Environment***

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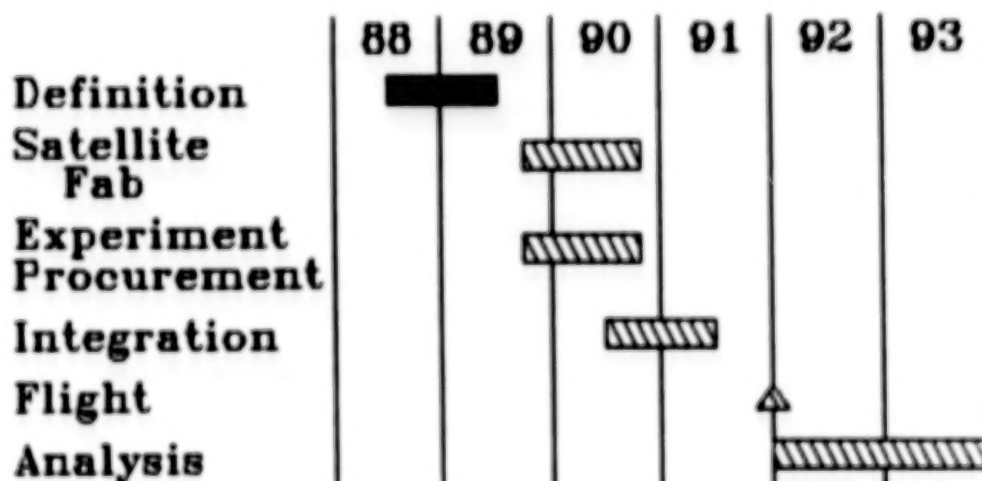
**Measurement Techniques Under Consideration**

- Mass Spectrometer
- QCM
- Osmium Detectors
- Surface erosion measurements

Optical

SEM

Scattering



<b>INSTEP88 Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>	<b>Experiment Descriptions</b>
<b>Out-Reach</b>	<div data-bbox="584 282 1122 492"> <p align="center"> <b>SPACE ENVIRONMENTAL EFFECTS</b>  <b>Atmospheric Effects and Contamination</b>  <b><i>Optical Properties Monitor (OPM) Experiment</i></b>  <b>Donald R. Wilkes</b>  <b>John M. Cockerham &amp; Associates</b>  <b>Contract: NAS8-37755, Marshall Space Flight Center, Jim Ziener</b> </p> </div> <div data-bbox="1323 282 1463 315"> <b>Out-Reach</b> </div>
<div data-bbox="685 562 1038 595"> <p align="center"><b><u>EXPERIMENT OBJECTIVE</u></b></p> </div> <div data-bbox="483 636 1165 696"> <p>To study the effects of the space environment, both natural and induced, on optical materials and thermal surfaces.</p> </div> <div data-bbox="510 754 1228 1106"> <ul style="list-style-type: none"> <li>• Develop a multifunction, reusable flight instrument for in-space optical studies</li> <li>• Determine the effects and damage mechanisms of the space environment on optical materials and thermal surfaces</li> <li>• Provide flight testing of critical spacecraft and optical materials</li> <li>• Validate ground test facilities and techniques</li> </ul> </div>	
<div data-bbox="752 1308 959 1341"> <p align="center"><b><u>BACKGROUND</u></b></p> </div> <div data-bbox="366 1348 1286 1559"> <ul style="list-style-type: none"> <li>• The natural and induced space environment can damage spacecraft materials</li> <li>• Space environmental effects and damage mechanisms are not well understood</li> <li>• The space environment cannot be fully simulated</li> <li>• There have been only limited in-space optical measurements of material properties</li> </ul> </div> <div data-bbox="715 1590 1004 1624"> <p align="center"><b><u>TECHNOLOGY NEED</u></b></p> </div> <div data-bbox="359 1639 1340 1971"> <ul style="list-style-type: none"> <li>• Longer duration, and more complex missions, such as Space Station, require better materials and better materials performance characterization</li> <li>• A better understanding of space environmental damage mechanisms will lead to: <ul style="list-style-type: none"> <li>– Better, more stable materials and coatings</li> <li>– Better, more accurate ground simulation testing</li> </ul> </li> <li>• Improved materials and better material performance characterization will lead to better, more cost effective, lower weight space systems designs</li> <li>• A multifunction, reusable flight instrument is needed for in-space optical studies</li> </ul> </div>	

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**SPACE ENVIRONMENTAL EFFECTS**  
**Atmospheric Effects and Contamination**  
**Optical Properties Monitor (OPM) Experiment**

Out-Reach

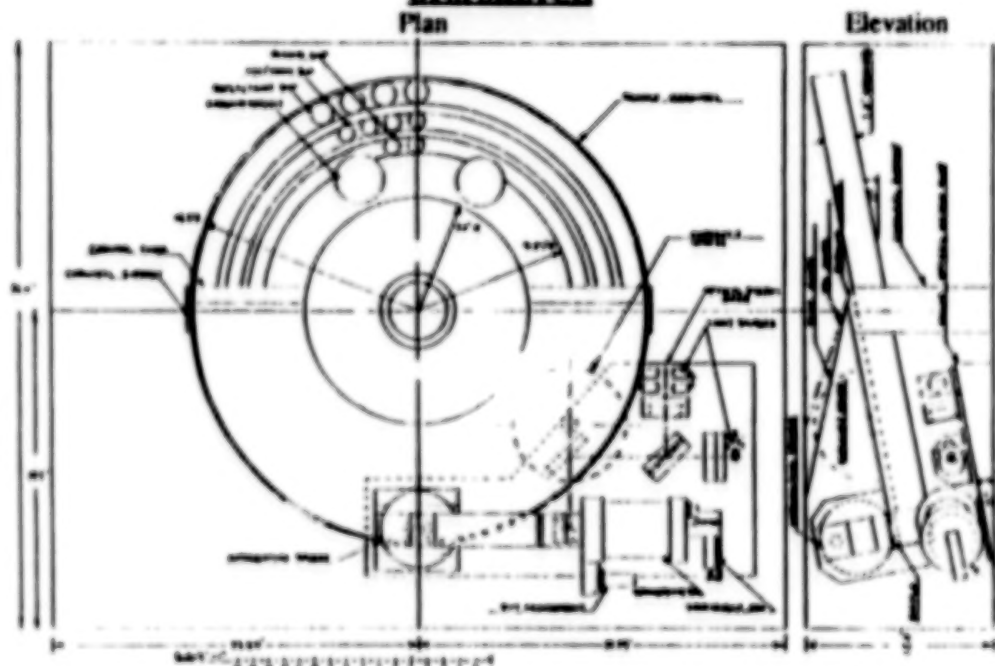
Donald R. Wilkos  
John M. Cockarham & Associates  
Contract: NAS8-37755, Marshall Space Flight Center, Jim Zielener

**EXPERIMENT DESCRIPTION**

Selected materials will be exposed to the near earth space environment and the effects measured through in-situ and post flight analysis.

- Active sample optical and thermal properties are measured by the in-situ measurement subsystem
  - Spectral total hemispherical reflectance - Integrating Sphere
  - Total integrated scatter - Coblentz Sphere
  - Spectral Transmittance
  - Total emittance/solar absorptance - Calorimetric Method
- Environmental monitors measure the sample exposure environment
  - Solar/earth irradiance - Radiometers
  - Molecular contamination - Temperature controlled quartz crystal microbalance
  - Atomic oxygen
- Passive sample optical and thermal properties, surface degradation, and surface contamination are determined by post-flight analysis.

**OPM SKETCH**



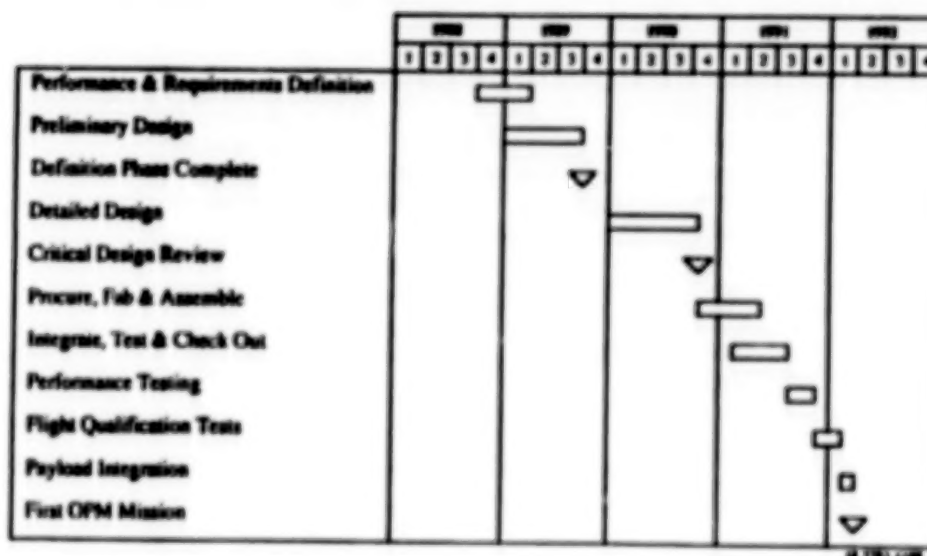
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**SPACE ENVIRONMENTAL EFFECTS**  
**Atmospheric Effects and Contamination**  
**Optical Properties Monitor (OPM) Experiment**

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Donald R. Wilkes  
John M. Cederham & Associates  
Contract: NAS8-37755, Marshall Space Flight Center, Jim Ziener

**OPM SCHEDULE**



**OPM SUMMARY**

- Definition phase effort is underway (September 16, 1988)
- Basic flight hardware concept proven on the LDEF Thermal Control Surfaces Experiment (TCSE)
- Total Integrated Scatter (TIS) and transmission measurements are added to the TCSE design
- Environmental monitors for molecular contaminants and atomic oxygen are added to the TCSE design
- The TIS measurement system design will be verified by laboratory breadboard testing
- 1978 TCSE design will be modernized to current technology
- OPM mission opportunities are being researched
- An OPM advisory committee is being formed



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**SPACE ENVIRONMENTAL EFFECTS**  
**Atmospheric Effects and Contamination**  
**Experimental Investigation of Spacecraft Glow**

Out-Reach

Gary Swenson

Lockheed Missiles & Space Co., Palo Alto Research Laboratory (teamed with Lockheed Houston)  
Contract: NAS9-17988, Johnson Space Center, Jim Veenline - ESS

**Experiment Objective**

Develop understanding of the physical processes leading to spacecraft glow phenomena, with emphasis on surface temperature and altitude effects. This development can be used to:

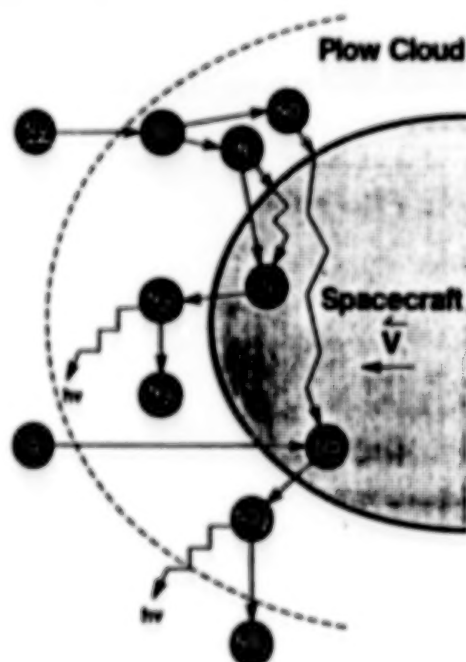
- Characterize optical instrument backgrounds
- Provide guidelines for thermal insulations
- Characterize material selection for light optics and associated spacecraft
- Affect flight-operation altitude selection for relevant missions

**Background/Technology Need**

Experimental data from STS missions suggest that cold surfaces result in increased surface catalysis with atmospheric constituents, resulting in brighter glow.

Confirming spectral and intensity data are needed from a temperature-monitored surface in ram. Intensities at different altitudes are desired in order to understand the synergistic effect of multiple atmospheric species. Spectral and intensity data from ultraviolet and infrared wavelengths are also required.

**Why a space experiment?** Glow contamination results from large fluxes ( $>10^{13} \text{ cm}^{-2}$ ) of fast atmospheric constituents (4-10 eV), catalytically reacting on surfaces to form excited-state molecules which emit glow. The combined fluxes and energies are not reproducible in ground facilities.



**Spacecraft-Atmospheric Interaction**

The top of the figure shows atmospheric  $\text{N}_2$  interacting with rebounding O and atom exchanging to form N and NO. The N is shown to contact N which has been deposited on the surface, and to recombine to form  $\text{N}_2^*$ . This excited state leads to  $\text{N}_2$  LBH emission which is predicted to be responsible for the low-altitude glow seen on the S3-4 satellite. The bottom of the figure illustrates atmospheric O impinging on NO which is weakly bound to the surface. The surface recombination will lead to  $\text{NO}^*$  and has been proposed as being responsible for the "red" shuttle glow.

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**SPACE ENVIRONMENTAL EFFECTS**  
**Atmospheric Effects and Contamination**  
**Experimental Investigation of Spacecraft Glow**

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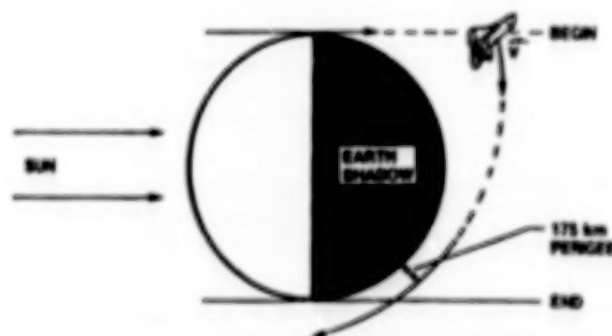
Gary Swenson

Lockheed Missiles & Space Co., Palo Alto Research Laboratory (teamed with Lockheed Houston)

Contract: NAS8-17988, Johnson Space Center, Jim Visentine - ESS

**Experiment Description**

The experiment hardware will include a 1 x 1 m flat plate with a material sample. The plate will be directed into atmospheric ram direction on orbit. The instrumentation includes a visible imaging spectrometer (400-800 nm), an IR detector (1-3  $\mu\text{m}$ ), and a far-ultraviolet imaging spectrometer (110-300 nm). The instrumentation will be mounted on an MPSS structure. An uplink command will activate the experiment, and an onboard recorder will log the data. Operation during four "shadowed" orbit periods is desired, at low altitude. At least two orbits of 175-km perigee are desired (as part of the STS reentry sequence).



**Breadboard Tests for Functionality, Response, and Sensitivity**

- Breadboard an image detector for the far-ultraviolet imaging spectrometer
  - Gated intensifier, plug coupled to a CCD
  - 110-300-nm response
  - RbTe photocathode
  - 25-mm diameter
  - 388 x 480 CCD array, thermoelectrically cooled to 230 K
  - Digital output
- Breadboard an IR detector
  - Dewar resident, single element
  - 1-5.5  $\mu\text{m}$  response
  - InSb element
  - Joule-Thompson cooled to 77 K
  - High-gain analog output

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**SPACE ENVIRONMENTAL EFFECTS**  
Atmospheric Effects and Contamination  
*Experimental Investigation of Spacecraft Glow*

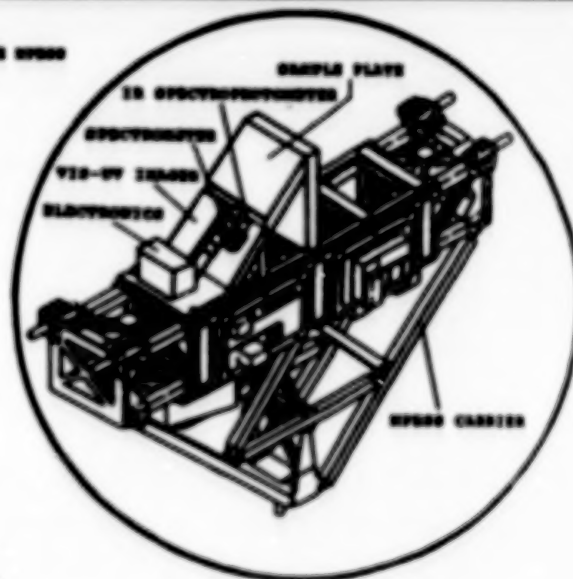
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Gary Swanson

Lockheed Missiles & Space Co., Palo Alto Research Laboratory (teamed with Lockheed Houston)

Contract: NAS9-17966, Johnson Space Center, Jim Visentine - ES5

- THE EXPERIMENT MAY ALSO BE FLIGHT ON THE SPACE  
WITH THE STATIONER-2 SYSTEM.



GLow EXPERIMENT SHOW ON SPACE CARRIER WITH STANDARD MEL CONFIGURATION

MASTER SCHEDULE

	YR 88				89				90				91				92				93				94				95			
	QTR				1234				1234				1234				1234				1234				1234				1234			
FORMAL REVIEWS																																
DEFINITION STUDY																																
SYSTEM DESIGN																																
FABRICATE AND ASSEMBLY																																
TESTING																																
FLIGHT OPERATIONS																																
DATA ANALYSIS																																
REFURBISHMENT																																

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**SPACE ENVIRONMENTAL EFFECTS**  
**Atmospheric Effects and Contamination**  
***Return Flux Experiment (REFLEX)***

In-Reach

J.J. Triclo and R. McInosh  
Goddard Space Flight Center

EXPERIMENT OBJECTIVES

\* CONTAMINATION MEASUREMENTS

- FULLY CHARACTERIZE THE S/C MOLECULAR CONTAMINATION ENVIRONMENT
- TOTAL CONTAMINATION ACCRETION FROM DIRECT FLUX AND RETURN FLUX
- INDIVIDUAL SPECIES ACCRETION FROM DIRECT FLUX AND RETURN FLUX
- VERIFICATION OF ALL AVAILABLE MASS TRANSFER CODES (NEWLY DEVELOPED AND CURRENT)
- VELOCITY/DIRECTION OF EACH SPECIE
- CHEMISTRY OF NATURAL + INDUCED SPECIES (GAS PHASE AND HETEROGENEOUS REACTIONS)

\* NATURAL ENVIRONMENT CHARACTERIZATION

- DIRECT MEASUREMENT OF CONCENTRATION OF SPECIES IN THE NATURAL ENVIRONMENT (ATOMIC OXYGEN, ATOMIC NITROGEN, O<sub>2</sub>, N<sub>2</sub>, CO, NO, AR, ETC.)

BACKGROUND/TECHNOLOGY NEED

- AVAILABLE DATA ON SPACECRAFT INDUCED ENVIRONMENT IS VERY SPARSE. NO SYSTEMATIC EFFORT TO MEASURE THE CONTAMINATION ENVIRONMENT AS A FUNCTION OF MISSION PARAMETERS HAS BEEN MADE TO DATE.
- EXISTING CONTAMINATION MODELS ARE NOT FLIGHT VERIFIED. THE MEAGER AMOUNT OF FLIGHT DATA SEEMS TO INDICATE GROSS INACCURACIES IN SOME AREAS (PARTICULARLY FOR THE RETURN FLUX COMPONENT OF THE MOLECULAR ENVIRONMENT).
- FLIGHT EXPERIMENTS ARE URGENTLY NEEDED TO GATHER DATA IN AN ORGANIZED MANNER.
- RELIABLE PREDICTIONS WILL ALLOW GREAT ECONOMICAL ADVANTAGE IN THE SIZING OF THE CONTAMINATION CONTROL ACTIVITIES FOR A LARGE NUMBER OF NASA PROGRAMS.



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**SPACE ENVIRONMENTAL EFFECTS**  
**Atmospheric Effects and Contamination**  
***Return Flux Experiment (REFLEX)***

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J.J. Trigo and R. McIntosh  
Goddard Space Flight Center

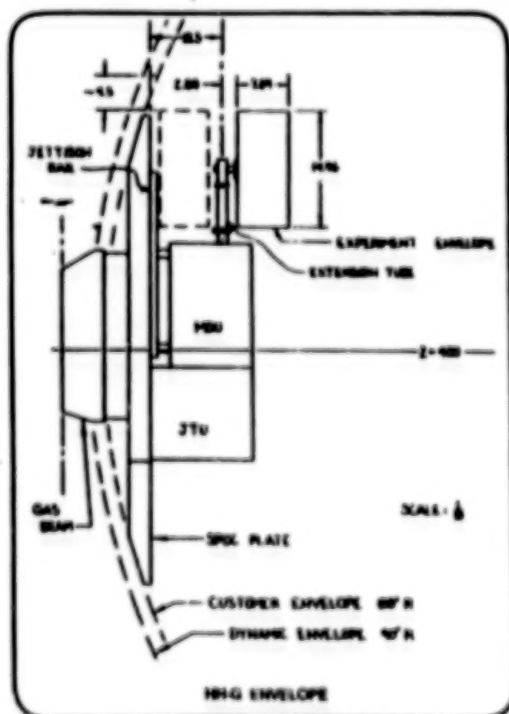
**EXPERIMENT DESCRIPTION**

**- MAJOR EXPERIMENT COMPONENTS:**

- 1)- SENSOR: MASS SPECTROMETER
- 2)- MOLECULAR SOURCE: NOBLE GAS
- 3)- CARRIER: TBD

**- COMPONENT FUNCTION:**

- 1)- SENSOR: DETECTION OF ALL MOLECULAR SPECIES OF INTEREST IN BOTH NATURAL AND SPACECRAFT INDUCED ENVIRONMENTS. CHEMICAL NATURE AND VELOCITY ARE OBTAINED AS A FUNCTION OF TIME.
- 2)- MOLECULAR SOURCE: PROVIDES A KNOWN INPUT TO THE S/C ENVIRONMENT FOR RETURN FLUX MEASUREMENTS.
- 3)- CARRIER: ALLOWS POSITIONING OF THE EXPERIMENT PACKAGE TO LOW/ZERO BACKGROUND LOCATIONS FOR EXTREMELY ACCURATE MEASUREMENTS OF LOW INTENSITY PHENOMENA (RETURN FLUX).

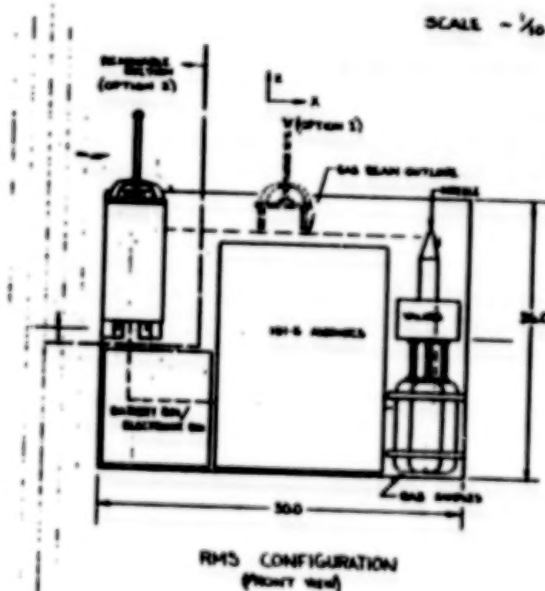


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**SPACE ENVIRONMENTAL EFFECTS**  
**Atmospheric Effects and Contamination**  
**Return Flux Experiment (REFLEX)**

In-Reach

J.J. Titolo and R. McIntosh  
Goddard Space Flight Center



SCHEDULE

- COMPLETE PHASE A: NOV 88
- PHASE B START: JAN 89
- PHASE C/D START: JAN 90

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**SPACE ENVIRONMENTAL EFFECTS**  
**Meteoroids and Debris**

In-Reach

***Debris Collision Warning Sensors***

Faith Vilas and David Thompson  
Johnson Space Center  
Solar System Exploration Division

**EXPERIMENT OBJECTIVE:**

CHARACTERIZE STATISTICALLY THE LEO DEBRIS ENVIRONMENT, CONCENTRATING ON OBSERVING DEBRIS OF SIZES DOWN TO 1 mm DIAMETER; OBTAINING BOTH VISIBLE PHOTOMETRY ( $\sim 0.55\mu\text{m}$ ) AND THERMAL RADIOMETRY ( $5\mu\text{m}$ ). TEST DETECTOR EFFECTIVENESS FOR SPACECRAFT DEBRIS COLLISION WARNING SYSTEM. DATA ACQUIRED WILL USED TO:

- MODEL EFFECTS (NOISE SOURCES, FALSE SIGNALS) WHICH SMALL DEBRIS PIECES COULD HAVE ON DEBRIS COLLISION WARNING SYSTEM OPERATION.
- OPTIMIZE DETECTOR SELECTION FOR DCW BY UNDERSTANDING ALBEDO VALUES AND THERMAL HEATING PROPERTIES OF LEO DEBRIS.
- CALCULATE DEBRIS FRAGMENT SIZES WITH ACCURATE ALBEDO MEASUREMENT.

**BACKGROUND/TECHNOLOGY NEED**

- LEO DEBRIS POPULATION INCREASING, PRODUCING INCREASED HAZARD TO SPACECRAFT.
- NEW CONCEPTS FOR PROTECTING SPACECRAFT MUST BE DEVELOPED.
  - ON-BOARD DETECTION WILL PROBABLY PLAY A KEY ROLE.
  - REQUIRES SCIENTIFIC TECHNIQUE AND TECHNOLOGY DEVELOPMENT.
- DATA AMOUNT AND QUALITY ARE WORST IN SIZE (1mm-10cm), SPECTRAL RANGES ( $0.55\mu\text{m}$ ,  $5\mu\text{m}$ ) WHERE INFORMATION IS MOST CRITICAL TO DEBRIS COLLISION WARNING SYSTEM DESIGN.

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**SPACE ENVIRONMENTAL EFFECTS**

In-Reach

Meteoroids and Debris

***Debris Collision Warning Sensors***

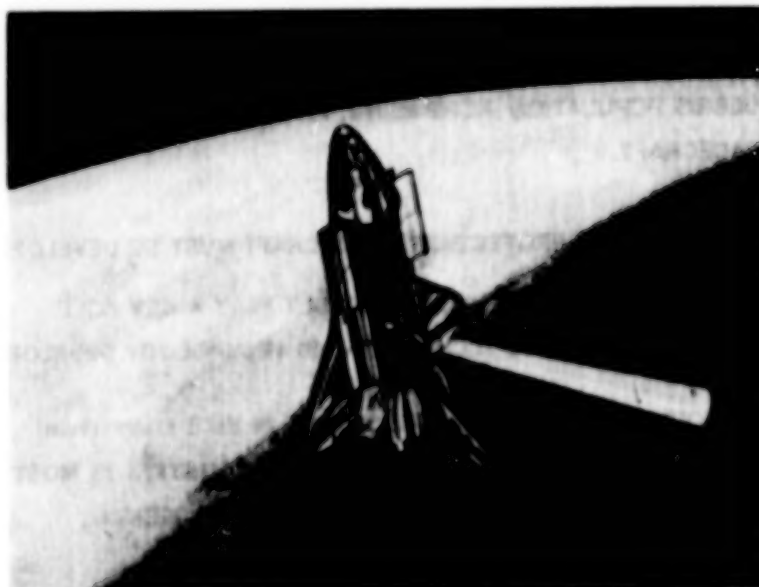
Fatih Vilas and David Thompson

Johnson Space Center

Solar System Exploration Division

**EXPERIMENT DESCRIPTION**

THE APPARATUS WILL CONSIST OF ONE 60-IN. F/1.2 TELESCOPE HAVING ALL-REFLECTING OPTICS WITH A 3.7° FIELD OF VIEW. A TEKTRONIX 2048x2048 PIXEL CCD RINGED BY SINGLE-ELEMENT 5- $\mu$ m DETECTORS, OPERATING AT A READOUT RATE OF ONE FRAME EVERY 1/10 SEC, IS LOCATED IN THE FOCAL PLANE. VISIBLE PHOTOMETRY, THERMAL RADIOMETRY, AND VELOCITY DATA CAN BE ACQUIRED ON DEBRIS PIECES PASSING THROUGH THE TELESCOPE'S FOV. EXPERIMENT MODES INCLUDE A BLIND SEARCH FOR DEBRIS DOWN TO 1mm DIAMETER, OBSERVATIONS OF KNOWN DEBRIS PIECES TRACKED BY USSPACECOM.





In-Reach

# SPACE ENVIRONMENTAL EFFECTS

In-Reach

Meteoroids and Debris

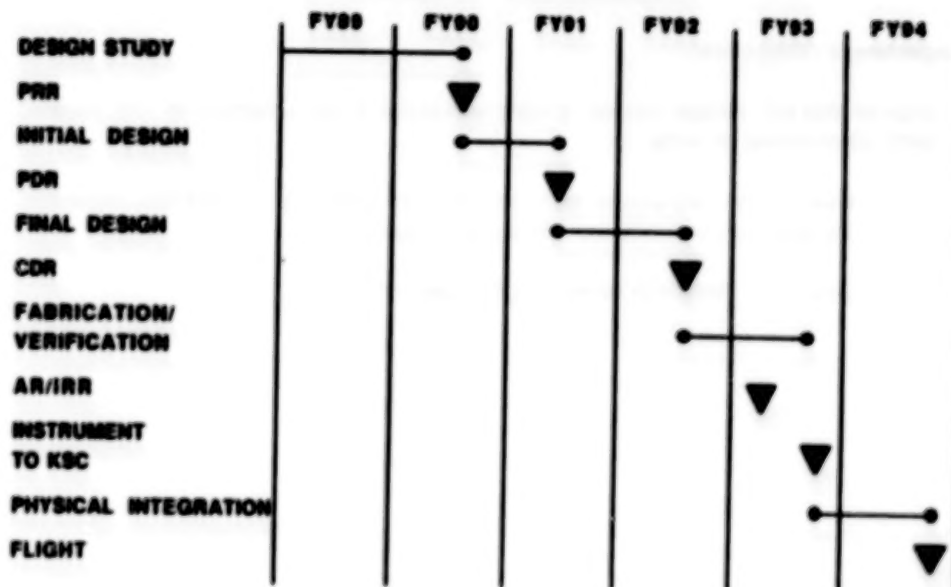
*Debris Collision Warning Sensors*

Faith Vilas and David Thompson

Johnson Space Center

Solar System Exploration Division

## PRELIMINARY SCHEDULE FOR PROPOSED FLIGHT EXPERIMENT



In-Reach

**SPACE ENVIRONMENTAL EFFECTS**  
**Atmospheric Effects and Contamination**

In-Reach

***Thin Foil X-Ray Optics Space Environment Contamination Experiment***

**R. Petra, P.J. Serfaty, C.A. Glasser**  
**Goddard Space Flight Center**

**Experiment Objective:**

Expose thin-foil, lacquer-coated, grazing incidence X-ray reflectors to low earth orbit environment in order to:

1. Measure the degradation of X-ray reflection efficiency of candidate mirror surfaces due to interaction with atomic oxygen
2. Determine the effectiveness of protective measures

**Background:**

- Thin-foil, conical imaging X-ray mirrors represent new technology X-ray astronomy instrumentation
- Mirror technology developed entirely within NASA (GSFC)
- Grazing incidence reflecting surfaces consist of lacquer-coated, high reflectivity aluminum foil, with evaporated 500 Angstrom gold layer
- Initial implementation on Broad Band X-Ray Telescope (STS-35, March 1990)
- Will be used or being studied for use on several long term X-ray astronomy missions:
  - ASTRO-D, 1993 (Japan/USA)
  - Spectrum-X, 1994 (USSR/Denmark/USA)
  - SpitzerSat, 1994 (W. Germany/USA)
- Lacquer coating technology has direct applications for other kinds of X-ray mirrors and for far and extreme ultraviolet optics
- Unclear how previous contamination studies relate to grazing incidence or lacquer coated surfaces, or to X-ray reflectivity

In-Reach

**SPACE ENVIRONMENTAL EFFECTS**

In-Reach

Atmospheric Effects and Contamination

***Thin Foil X-Ray Optics Space Environment Contamination Experiment***

R. Petro, P.J. Serlentico, C.A. Glasser  
Goddard Space Flight Center



Thin foil conical imaging X ray mirror for the Broad Band X Ray Telescope instrument

**Experiment Description**

Baseline approach - low cost, minimal STS interface

Strategy - use GAS carrier, develop hardware quickly to allow possibility of manifesting with larger experiments with similar mission requirements (e.g., FOIM-3, IFCE)

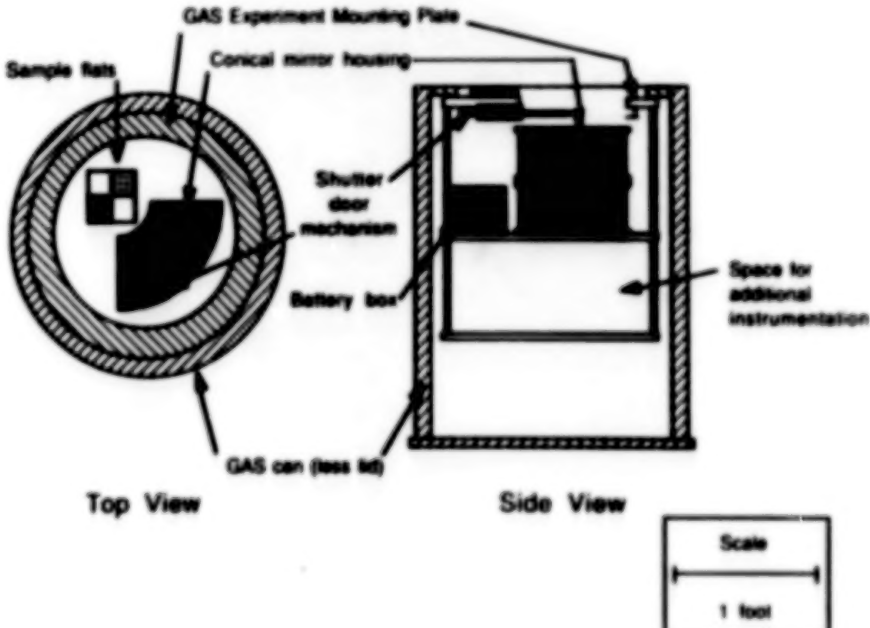

**Key Components -**

Conical mirror quadrant - holds reflector samples at proper incidence angles

Sample tray - holds thin foil mirror samples at normal incidence

Shutter mechanism - shuts slowly over duration of experiment to allow determination of degradation vs. exposure time

Carrier - GAS can with Motorized Door Assembly

INSTEP88 Workshop OAST Technology For the Future Part 1: Executive Summary & Experiment Descriptions		Experiment Descriptions	
In-Reach	<b>SPACE ENVIRONMENTAL EFFECTS</b> Atmospheric Effects and Contamination <b>Thin Foil X-Ray Optics Space Environment Contamination Experiment</b>  R. Petre, P.J. Serfentisco, C.A. Glasser Goddard Space Flight Center		In-Reach
<b>Thin Foil Mirror Contamination Experiment</b>			
 <p>Top View</p> <p>Side View</p> <p>Scale 1 foot</p>			
			
Thin foil conical mirror quadrant to be used for holding samples for contamination experiment			



In-Reach

**SPACE ENVIRONMENTAL EFFECTS**

In-Reach

Atmospheric Effects and Contamination

***Thin Foil X-Ray Optics Space Environment Contamination Experiment***

R. Peña, P.J. Santolucito, C.A. Glasser  
Goddard Space Flight Center

**Milestones**

In-Reach proposal submitted	July, 1986
In-Reach proposal accepted; begin Phase A study	August, 1987
Finish Phase B definition phase	November, 1988
Begin Phase C/D development (pending funding)	January, 1989
Submit GAS reservation	January, 1989
Deliver complete instrument to GAS program	June, 1990

Out-Reach

# POWER SYSTEMS AND THERMAL MANAGEMENT

Out-Reach

Conventional Power Systems

## Sodium-Sulfur Battery

Body Chang

Ford Aerospace Corporation, Space Systems Division  
 Contract: NAS3-25355, Lewis Research Center, H.F. Leibicki

### NaS BATTERY TECHNOLOGY BENEFITS -

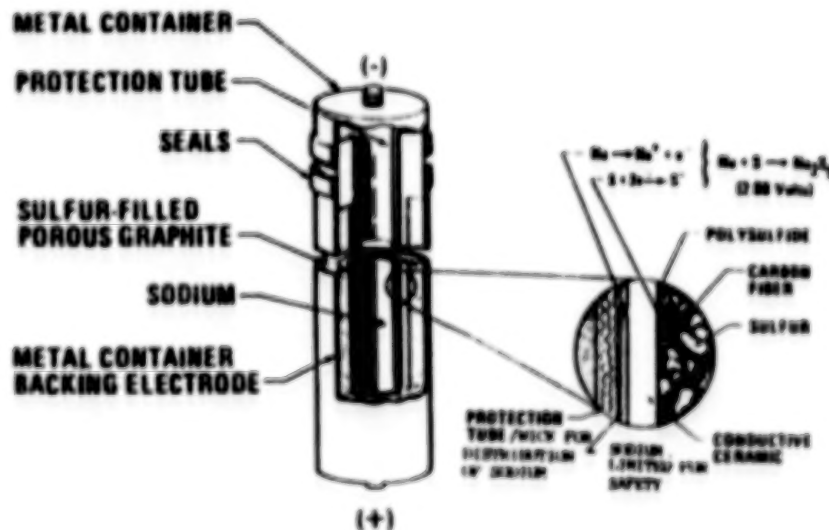
- § 1.1-1.7 MW/KW SAVING IN LAUNCH FOR GEO MISSION OVER NiH2 BATTERY
- § 0.3-0.4 MW/KW SAVING IN LAUNCH FOR LEO MISSION OVER NiH2 BATTERY

### EXPERIMENT OBJECTIVE

TO DESIGN AN EXPERIMENT THAT WILL DEMONSTRATE OPERATION OF  
 SODIUM-SULFUR BATTERY/CELLS UNDER SPACE ENVIRONMENTS WITH  
 PARTICULAR EMPHASIS ON EVALUATION ON MICROGRAVITY EFFECTS.

- TO EVALUATE CHARGE AND DISCHARGE CHARACTERISTICS AS AFFECTED BY FLUID REACTANT DISTRIBUTIONS
- TO DETERMINE REACTANT DISTRIBUTIONS UNDER MICROGRAVITY CONDITION
- TO UNDERSTAND CURRENT & THERMAL DISTRIBUTION WITHIN CELLS
- TO EVALUATE FREEZE THAW EFFECTS
- TO EVALUATE COLD VS WARM LAUNCH
- TO EVALUATE MULTICELL OPERATION

### BACKGROUND /TECHNOLOGY



Out-Reach

## POWER SYSTEMS AND THERMAL MANAGEMENT

Out-Reach

Conventional Power Systems

Sodium-Sulfur Battery

Bucky Chung

Ford Aerospace Corporation, Space Systems Division

Contract: NAS3-25366, Lewis Research Center, H.F. Lebeck

### EXPERIMENTAL APPROACH

- O SELECT ONLY THOSE TESTS THAT ARE CRITICAL AND EXPECTED TO DIFFER UNDER MICROGRAVITY CONDITION.
- O 'SPINNERS' CAN BE DUPLICATED ON EARTH.
- O CORRELATE CELL CHARACTERISTICS BEFORE/DURING/FOLLOWING SPACE FLIGHT TO ELIMINATE EXTRANEIOUS VARIABLES
- O INCORPORATE ADDITIONAL CONTROL CELLS

### EXPERIMENT DESCRIPTION

#### I. CELL CHARACTERIZATION TEST

- O RATED 40 AH BASELINE CELLS
- O 8 CELLS FOR SPACE; 4 CELLS FOR GROUND CONTROL
- O COLD LAUNCH
- O TWO OPERATING TEMPERATURES : 275-300; 350-375°C
- O CHARGE RATES: C/8, C/2, 34C, C PLUS TAPER
- O DISCHARGE RATES C/2; C; 1.5C, 2C PLUS PULSES TO -4C
- O CELL IMPEDANCE & EFFICIENCY

#### II. REACTANT DISTRIBUTION DESTRUCTIVE PHYSICAL ANALYSIS

- O 8 CELLS REUSED AFTER NO. I

#### III. REACTANT DISTRIBUTION TEST

- O SPECIAL INSTRUMENTED 40 AH CELLS
- O 2 CELLS IN SPACE, 1 CELL ON GROUND
- O TO DETERMINE CURRENT DENSITY VS. AXIAL POSITION DURING DISCHARGE/CHARGE AND OPEN CIRCUIT

#### IV. FREEZE/THAW TEST

- O RATED 40 AH BASELINE CELLS
- O 4 CELLS FOR SPACE; 2 CELLS ON GROUND

#### V. WARM LAUNCH TEST

- O RATED 40 AH BASELINE CELLS
- O 4 CELLS FOR SPACE
- O 200°C PRELAUNCH/LAUNCH

#### VI. CELL CYCLE TEST

- O MULTI-CELL OPERATION
- O EARLY-LIFE LEO CHARACTERISTICS

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## POWER SYSTEMS AND THERMAL MANAGEMENT

Out-Reach

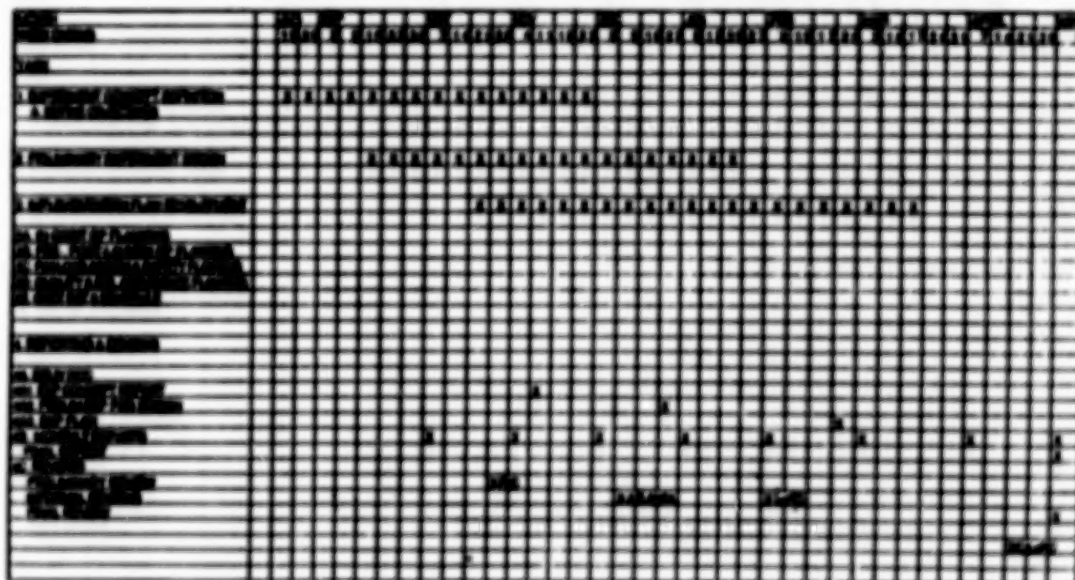
### Conventional Power Systems

### Sodium-Sulfur Battery

Redy Chang

Ford Aerospace Corporation, Space Systems Division  
Contract: NAS3-25355, Lewis Research Center, H.F. Lelbeck

#### NA-S BATTERY FLIGHT EXPERIMENT DEFINITION MASTER SCHEDULE



#### SUMMARY

- NA-S BATTERY TECHNOLOGY OFFERS SIGNIFICANT PAYOFF FOR SPACE APPLICATIONS, BUT OPERATION IN SPACE ENVIRONMENT IS UNKNOWN.
- FURTHER ENHANCEMENT OF NA-S EXCELLENT PERFORMANCE AND CYCLE LIFE COULD OCCUR DUE TO MORE UNIFORM CONDITION WITHIN CELL DUE TO MICROGRAVITY CONDITIONS.
- SOME HYPOTHESES PREDICT PERFORMANCE LIMITATIONS WITH IMPACT ON CELL LIFE IN LOW-GRAVITY ENVIRONMENTS.
- FLIGHT EXPERIMENTS HAVE BEEN SELECTED TO DOCUMENT AND CORRELATE CRITICAL CELL CHARACTERISTICS UNDER SPACE ENVIRONMENTS WITH KNOWN RESPONSE ON EARTH.
- RESULTING DATA BASE WILL MINIMIZE COSTS OF SUBSEQUENT LARGER-SCALE APPLICATION-SPECIFIC EXPERIMENTS.
- CYCLE LIFE EFFORTS CAN NOT BE ADDRESSED IN SIMPLE STS FLIGHT WOULD REQUIRE EXTENDED ORBIT EXPERIMENT.

INSTEP88 Workshop OAST Technology For the Future Part 1: Executive Summary & Experiment Descriptions	Experiment Descriptions
Out-Reach	<div> <div> <b>POWER SYSTEMS AND THERMAL MANAGEMENT</b>            Conventional Power Systems  <i>Utilized Regenerative SPE® Fuel Cell</i>            Timothy A. Nalotte            United Technologies Corporation, Hamilton Standard Division            Contract: NAS8-18001, Lewis Research Center, Rick Baldwin         </div> <div>Out-Reach</div> </div>
<p><b>Experiment Objective:</b></p> <ul style="list-style-type: none"> <li>• Evaluate zero gravity operation of a passive Utilized Regenerative SPE Fuel Cell (URFC) electrical energy storage system             <ul style="list-style-type: none"> <li>- Cell module                 <ul style="list-style-type: none"> <li>• Reversible SPE Fuel Cell/ electrolyzer operation</li> <li>• Passive phase separation</li> <li>• Static vapor feed</li> </ul> </li> <li>- System                 <ul style="list-style-type: none"> <li>• Passive fluid management</li> <li>• Passive thermal control</li> </ul> </li> </ul> </li> </ul>	
<p><b>Background:</b></p> <ul style="list-style-type: none"> <li>• Existing spacecraft energy storage and fluid management systems are heavy and/or complex</li> <li>• SPE fuel cells and SPE electrolyzers are mature technologies</li> <li>• Utilized regenerative fuel cells offer potential reductions in system complexity, weight, and volume</li> </ul> <p><b>Technology need:</b></p> <ul style="list-style-type: none"> <li>• Reliability is enhanced through the use of passive fluid and thermal management technologies</li> <li>• Applications include electrical energy storage for Space Station, satellites, rechargeable rover vehicles, peak power requirements, and any orbiting system requiring electrical energy storage</li> </ul>	



Out-Reach

## POWER SYSTEMS AND THERMAL MANAGEMENT

Out-Reach

Conventional Power Systems

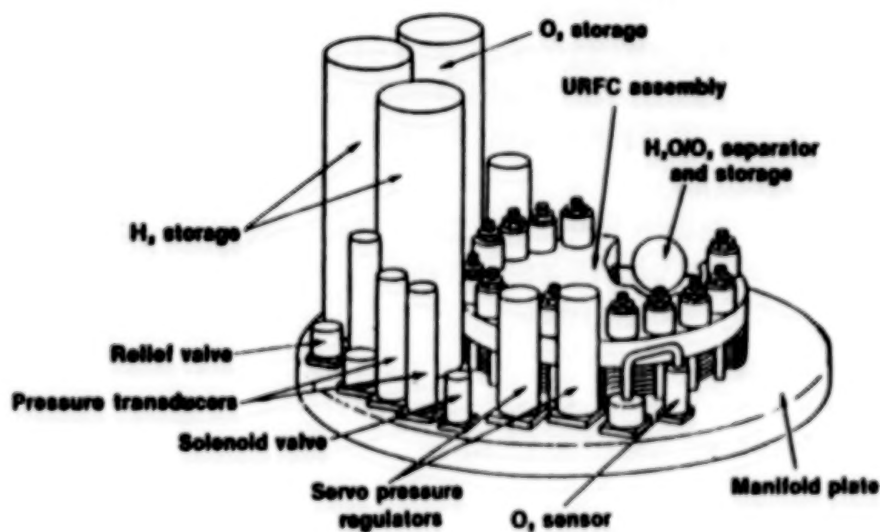
*Unitized Regenerative SPE® Fuel Cell*

Timothy A. Nalella

United Technologies Corporation, Hamilton Standard Division

Contract: NAS9-18001, Lewis Research Center, Rick Baldwin

### Packaging Concept



Finalize concept

System design

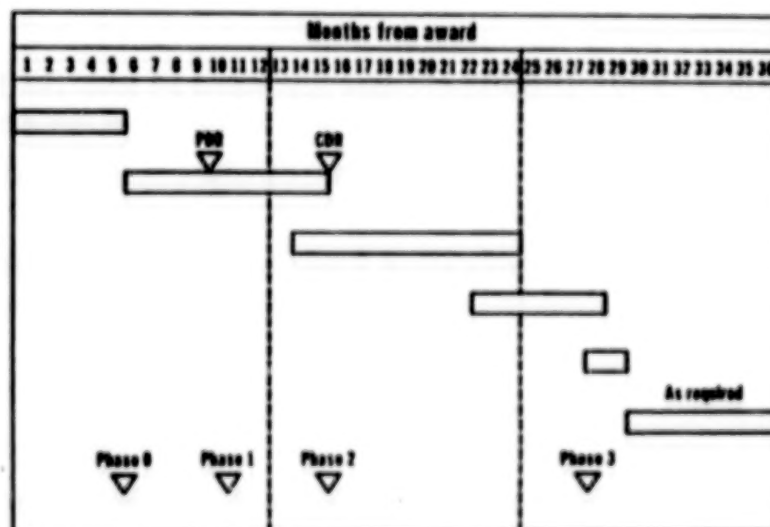
Fabrication/assembly

Test program

Refurbish & ship

Mission support

Safety review



Out-Reach

# **POWER SYSTEMS AND THERMAL MANAGEMENT**

Out-Reach

Conventional Power Systems

*Utilized Regenerative SPE® Fuel Cell*

Timothy A. Naletta

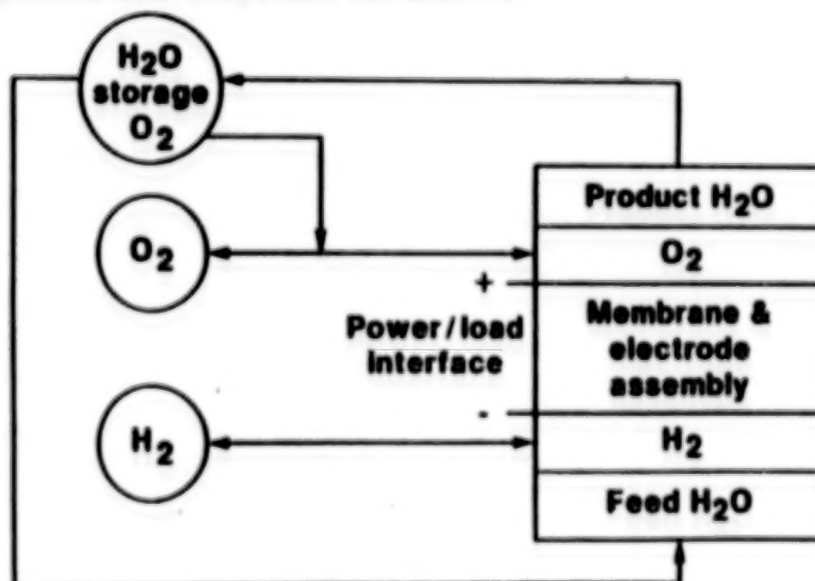
United Technologies Corporation, Hamilton Standard Division

Contract: NAS9-18001, Lewis Research Center, Rick Baldwin

## **Experiment Description:**

- URFC system will demonstrate a simple passive means of electrical energy storage for space applications employing passive fluid and thermal management technologies
- System parameters such as temperatures, pressures, voltage, and current will be measured for purposes of control and analysis
- Packaging concept depicts the "Get Away Special" carrier option but is easily adapted to other options
- Experiment will be self-contained
- Component selection and safety consideration based on mature flight designs

## **Simplified URFC system schematic**



In-Reach

## POWER SYSTEMS AND THERMAL MANAGEMENT

In-Reach

Dynamic and Nuclear Power Systems

### *Thermal Energy Storage Flight Experiments for Solar Dynamic Power Systems*

David Namkoong, Jenni Ling, Steve Johnson, Barbara Helzer, Tom Foster  
Lewis Research Center (Boeing, Contract NAS3-25364)

#### OBJECTIVE

EVALUATION OF PHASE CHANGE THERMAL ENERGY STORAGE (TES) SYSTEM AND MATERIALS IN MICROGRAVITY.

#### ISSUES

##### PROGRAMMATIC

- TES CRITICAL TO EFFICIENT OPERATION OF THE RECEIVER SYSTEM.
- FLIGHT TESTS ARE REQUIRED TO ASSESS VOID BEHAVIOR OF ADVANCED TES MATERIALS UNDERGOING REPEATING PHASE CHANGE IN MICROGRAVITY.
- COMPREHENSIVE APPROACH REQUIRES ANALYTICAL UNDERSTANDING AND EXPERIMENTAL VERIFICATION -- NEEDED FOR ADVANCED HEAT RECEIVER DESIGN PROCESS.

##### TECHNICAL

- VOID SHAPE AND LOCATION
- EFFECT OF VOID ON HEAT TRANSFER MECHANISMS
- COMPARISON BETWEEN 1-g AND MICROGRAVITY PERFORMANCE
- EFFECT OF STORAGE MATERIAL THERMAL/PHYSICAL PROPERTIES ON SYSTEM PERFORMANCE
- LACK OF A VALIDATED COMPUTER MODEL TO PREDICT PERFORMANCE TES SYSTEMS IN MICROGRAVITY

#### APPROACH

##### STSE DEFINITION

- DEFINE SPECIFIC EXPERIMENT OBJECTIVES AND REQUIREMENTS
- DEVELOP PRELIMINARY DESIGN OF EXPERIMENT TO ACCOMMODATE MULTIPLE TES CONCEPTS
- CONDUCT TRADE STUDIES, ANALYSES, AND GROUND TESTS
- PREPARE PROGRAM PLAN, SCHEDULE, AND COST

##### TEST

- DEVELOP AN ANALYTICAL AND COMPUTATIONAL BASIS TO PREDICT TRANSIENT BEHAVIOR OF TES MATERIALS, PARTICULARLY VOID SHAPE AND LOCATION, UNDER MICROGRAVITY
- CONDUCT MICROGRAVITY EXPERIMENTS TO ESTABLISH DATA BANK OF TES MATERIALS UNDER 1-g AND MICROGRAVITY
- VERIFY CAPABILITY OF DEVELOPED COMPUTER CODE TO PREDICT VOID LOCATION AND THERMAL HISTORY OF TES SYSTEM UNDERGOING PHASE CHANGE IN MICROGRAVITY

In-Reach

# POWER SYSTEMS AND THERMAL MANAGEMENT

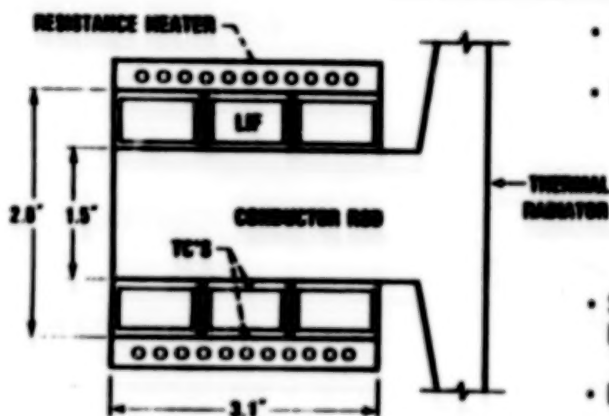
In-Reach

Dynamic and Nuclear Power Systems

## Thermal Energy Storage Flight Experiments for Solar Dynamic Power Systems

David Hardsong, Junt Ling, Steve Johnson, Barbara Helzer, Tom Foster  
Lewis Research Center (Boeing, Contract NAS3-25384)

### TEST EXPERIMENT



• "GAS" CAN EXPERIMENTAL PACKAGE

• FOUR EXPERIMENTS:

LF	1121 K
CeF <sub>3</sub> /MgF	1290 K
*GERMANIUM	1210 K
*HSI	1205 K

• SUNSHADE PERIODS OF 60/34 MINUTES PER CYCLE; 5 CYCLES

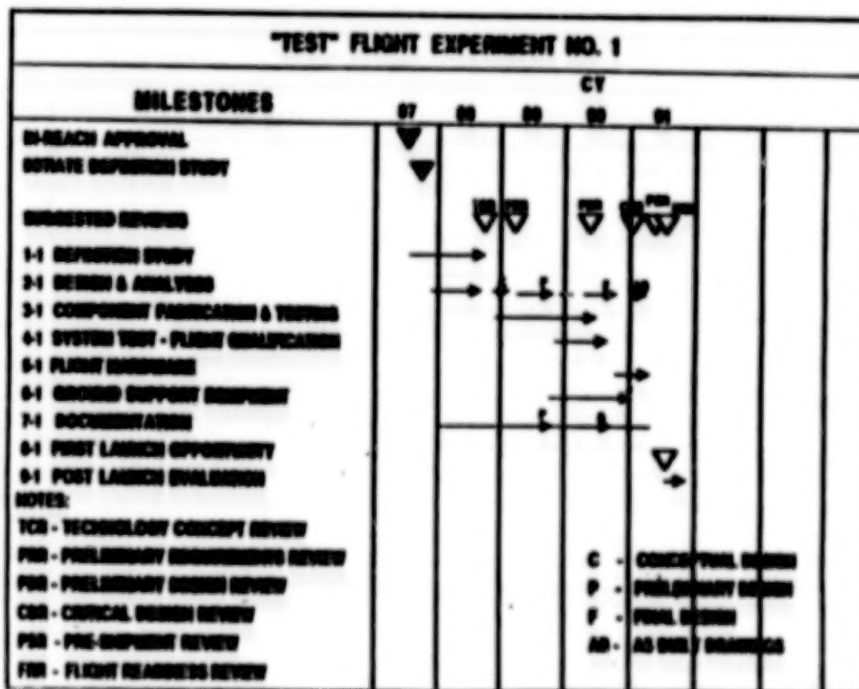
• RESULTS:

TEMPERATURE MEASUREMENTS

POST-TEST EXAMINATION OF VOID SHAPE, LOCATION

COMPARISON WITH ANALYTICAL PREDICTION

TES EXPERIMENT NO. 1



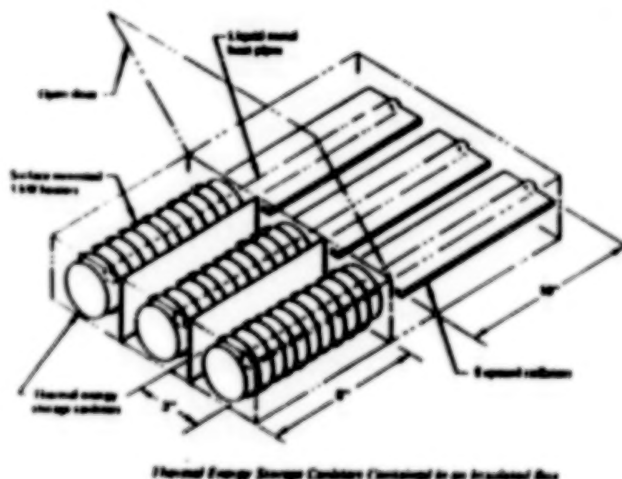
**Infants**

### Thermal Energy Storage Flight Experiments for Solar Dynamic Power Systems

## STSE EXPERIMENT

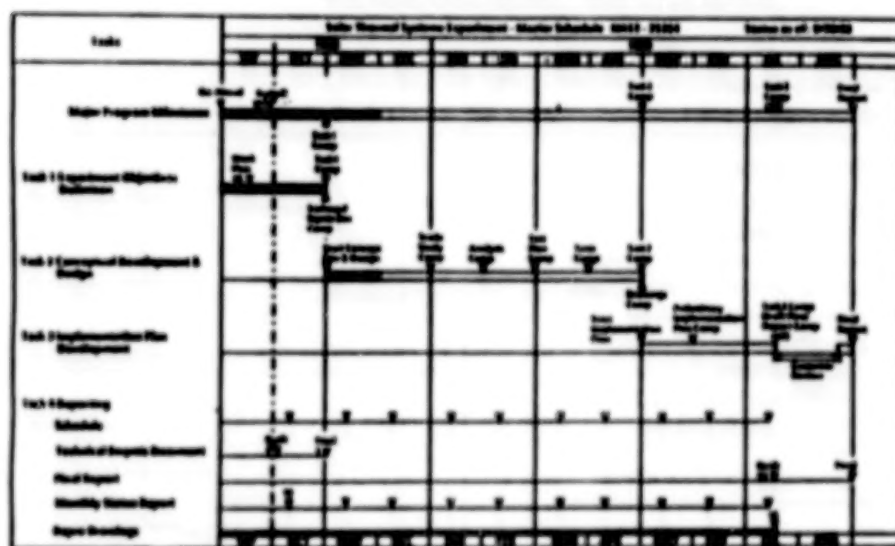
- COMPATIBLE WITH HITCH-HIKER
- DESIGNED FOR MODULARITY
- MULTIPLE CONCEPTS TESTED SIMULTANEOUSLY
- TEMPERATURE DISTRIBUTION AND HEAT FLUX MEASURED

- VERIFY THERMAL PERFORMANCE IN MICROGRAVITY
- VERIFY NON-DESTRUCTIVE METHODS OF DETERMINING VOID DISTRIBUTION
- COMPARE VOID DISTRIBUTION AND VOID MANAGEMENT FOR 1-g AND MICROGRAVITY ENVIRONMENTS
- VALIDATE PERFORMANCE PREDICTION METHODS



**Thermal Energy Storage Cylinders Designed to an Industrial Standard**

Solar Thermal Systems Experiment - Winter Schedule 2023-2024





Out-Reach

**POWER SYSTEMS AND THERMAL MANAGEMENT**  
Thermal Management

Out-Reach

*Investigation of Microgravity Effects on Heat Pipe Thermal Performance and Working Fluid Behavior*

George L. Patschman

Hughes Aircraft Company, Electron Dynamics Division

Contract: NAS5-30359, Goddard Space Flight Center, Roy McIntosh

**EXPERIMENT OBJECTIVE**

**DEVELOP IN-DEPTH UNDERSTANDING OF THE BEHAVIOR OF HEAT PIPES IN SPACE. BOTH CONSTANT CONDUCTANCE HEAT PIPES WITH AXIAL GROOVES AND VARIABLE CONDUCTANCE HEAT PIPES WITH WICKS WILL BE INVESTIGATED. THIS UNDERSTANDING WILL BE APPLIED TO THE DEVELOPMENT OF:**

- **IMPROVED PERFORMANCE OF HEAT PIPES SUBJECTED TO VARIOUS ACCELERATIONS IN SPACE.**
- **MORE EFFICIENT AND RELIABLE SPACECRAFT THERMAL MANAGEMENT SYSTEMS.**
- **LIGHTER WEIGHT SPACECRAFT THERMAL SYSTEMS.**

**BACKGROUND/TECHNOLOGY NEED**

**A PROBLEM THAT OFTEN ARISES IS HOW TO USE HEAT PIPE GROUND TEST DATA TO MAKE MICRO-GRAVITY PERFORMANCE PREDICTIONS. DURING GROUND TESTING, GRAVITY DOMINATES THE CAPILLARY FORCES AND BECOMES A LIMITING FACTOR. MOREOVER, BOTH THERMAL PERFORMANCE AND VEHICLE STABILIZATION ARE AFFECTED BY SPACECRAFT ACCELERATIONS CAUSED BY:**

- **MOTION IN ORBIT**
- **CHANGING ORBITS**
- **THREAT AVOIDANCE**

In-Reach

## POWER SYSTEMS AND THERMAL MANAGEMENT

In-Reach

### Thermal Management

#### *Investigation of Microgravity Effects on Heat Pipe Thermal Performance and Working Fluid Behavior*

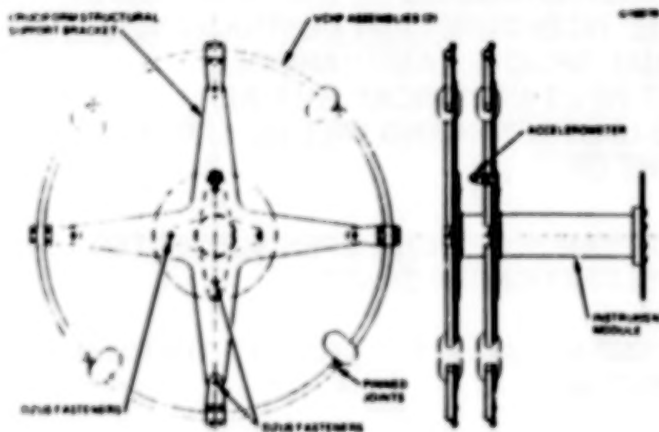
George L. Helechman

Hughes Aircraft Company, Electron Dynamics Division

Contract: NAS5-30359, Goddard Space Flight Center, Roy McIntosh

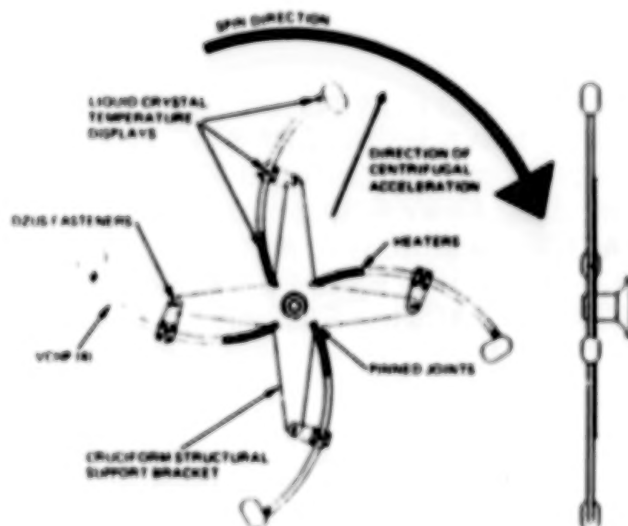
#### EXPERIMENT DESCRIPTION

THE APPARATUS WILL PROVIDE THE ABILITY TO SPIN 4 HEAT PIPES, MOUNTED IN A HOOP ASSEMBLY, UP TO SEVERAL HUNDRED RPM, AND TO RECORD THE NUTATION ACCELERATION USING AN INFRARED TELEMETRY SYSTEM. THE NUTATION DIVERGENCE FLIGHT TEST MEASURES THE EXPONENTIAL TIME CONSTANT FOR NUTATION DIVERGENCE OF A SPINNING MODEL WITH CIRCUMFERENTIAL HEAT PIPES.



#### EXPERIMENT DESCRIPTION

THE APPARATUS WILL PROVIDE THE ABILITY TO SPIN 4 HEAT PIPES, MOUNTED IN A RADIAL CONFIGURATION, UP TO 100 RPM TO FORCE THE WORKING FLUID TO ONE OF THE HEAT PIPE. NEXT, THE ASSEMBLY WILL BE BROUGHT TO REST, AND THE EVAPORATOR PORTION OF EACH HEAT PIPE WILL BE HEATED USING BATTERY POWERED HEATERS. REPRIMING RATES, EFFECT OF EXCESS LIQUID AND FLUID DISTRIBUTION WILL BE EVALUATED USING TEMPERATURE SENSITIVE LIQUID CRYSTALS.



<b>INSTEP88 Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>	<b>Experiment Descriptions</b>
<b>In-Reach</b>	<b>In-Reach</b>
<p align="center"> <b>POWER SYSTEMS AND THERMAL MANAGEMENT</b>  <b>Thermal Management</b>  <i>Investigation of Microgravity Effects on Heat Pipe Thermal Performance and Working Fluid Behavior</i>  <b>George L. Pleschman</b>  Hughes Aircraft Company, Electron Dynamics Division  Contract: NASS-30358, Goddard Space Flight Center, Roy McIntosh </p>	
<div data-bbox="388 546 1256 1144" data-label="Image"> </div> <p align="center"><b>GROOVED CONSTANT CONDUCTANCE HEAT PIPE</b></p>	
<div data-bbox="396 1323 1249 1921" data-label="Image"> </div> <p align="center"><b>VARIABLE CONDUCTANCE HEAT PIPE WITH CENTRAL CORE WICK</b></p>	

In-Reach

**POWER SYSTEMS AND THERMAL MANAGEMENT**  
Thermal Management

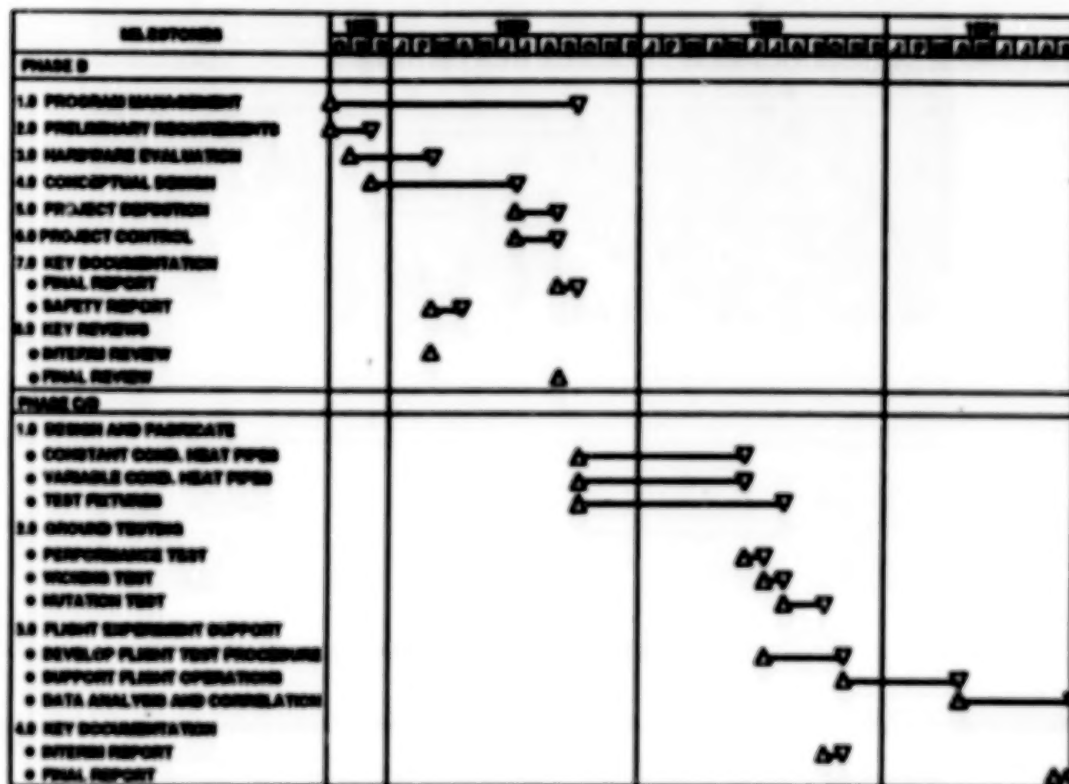
In-Reach

**Investigation of Microgravity Effects on Heat Pipe Thermal Performance and Working Fluid Behavior**

George L. Polachman

Hughes Aircraft Company, Electron Dynamics Division

Contract: NAS5-30058, Goddard Space Flight Center, Roy McIntosh



Out-Reach

# POWER SYSTEMS AND THERMAL MANAGEMENT

Out-Reach

## Thermal Management

### A High-Efficiency Thermal Interface Between a Two-Phase Fluid Loop and a Heat Pipe Radiator

John A. Polner

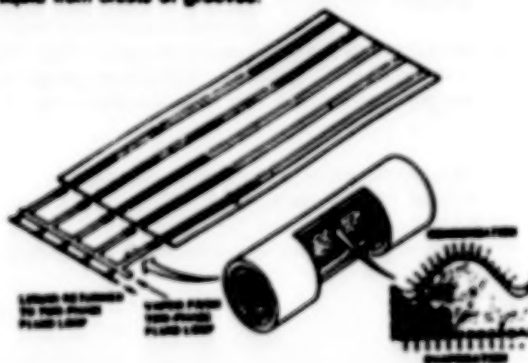
TRW, Space and Technology Group

Contract: NAS5-30375, Goddard Space Flight Center, Roy Mcintosh

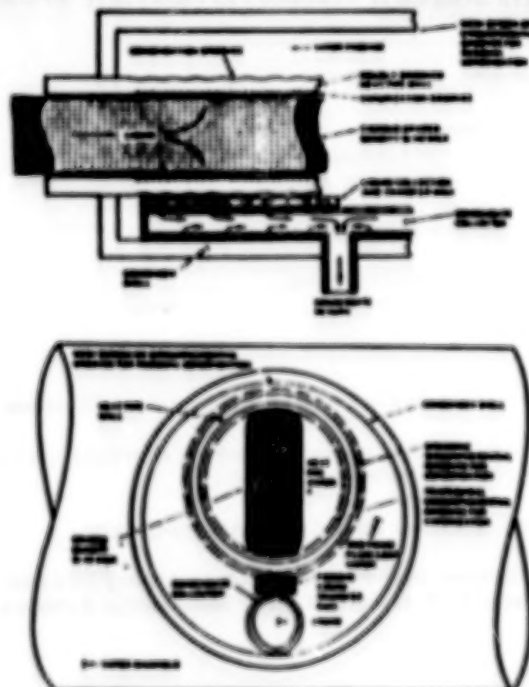
## EXPERIMENT OBJECTIVE

Characterize the microgravity performance of a High-Efficiency Thermal Interface (HETI) which thermally couples a two-phase fluid loop to a heat pipe radiator.

- For high-power spacecraft which must reject 10 to 100 kW of waste heat, two-phase fluid loops will be required to collect and transport heat, and large deployed radiators will be needed to reject the waste heat to space.
- High efficiency (low  $\Delta T$ ) interface required between fluid loop and radiator to minimize radiator size and weight.
- Vapor from two-phase loop condenses on Gregorig-grooved exterior of heat pipe. Gregorig grooves use capillary forces to drain liquid from crests of grooves.
- Fibrous wick structure transfers liquid from Gregorig groove troughs to liquid return line.
- Quantities of interest:
  - a) Condensation "h" on Gregorig grooves (predicted value = 50 kW/m<sup>2</sup>-K)
  - b) Evaporation "h" in heat pipe
  - c) Condensation "h" in heat pipe



## DETAILS OF THE HIGH-EFFICIENCY THERMAL INTERFACE





Out-Reach

**POWER SYSTEMS AND THERMAL MANAGEMENT**

Out-Reach

**Thermal Management**

***A High-Efficiency Thermal Interface Between a Two-Phase Fluid Loop and a Heat Pipe Radiator***

**John A. Puhar**

TRW, Space and Technology Group

Contract: NAS5-30375, Goddard Space Flight Center, Roy McIntosh

**BACKGROUND**

- o TRW developed the High Efficiency Thermal Interface (HETI) under the Air Force Wright Aeronautical Laboratory-sponsored High Power Spacecraft Thermal Management Study (Contract No. F33615-84-C-2414).
- o Prior to development of HETI, no thermal bus-to-radiator heat exchangers suitable to high-power missions (excluding Space Station) were available.
- o Ground testing of a single heat pipe version of the HETI resulted in heat transfer coefficients of the order of  $10 \text{ kW/m}^2\text{-K}$ . Satisfactory ground testing is difficult since capillary forces and gravitational body forces are of the same order of magnitude.
- o Microgravity testing is required to determine:
  - a) heat transfer coefficients;
  - b) startup behavior; and
  - c) response to suddenly increased or decreased heat loads.

**EXPERIMENT DESCRIPTION**

- o Experiment will be configured for Get Away Special or Hitchhiker-G carrier.
- o Key components will include:
  - capillary pumped loop (CPL) including evaporator pump, liquid and vapor transport lines, accumulator (reservoir), and subcooler;
  - two slab wick heat pipes
  - HETI which accommodates two heat pipes
  - radiator panel
  - battery and power control electronics; and
  - data acquisition electronics package.
- o Heat pipes and CPL will use ammonia as the working fluid.
- o Experiment will be heat sink limited. Increase of radiator mass will alleviate this problem.
- o Experiment will be instrumented so that condensation and evaporation heat transfer coefficients in HETI and heat pipes may be calculated.
- o Radiator panel must accommodate two heat pipes and liquid subcooler.
- o Experiment will be designed to permit preliminary ground testing (heat pipes in reflux mode, evaporator pump of CPL below HETI, gravity-aided drainage of ammonia from Gregor's grooves).

Out-Reach

# POWER SYSTEMS AND THERMAL MANAGEMENT

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## Thermal Management

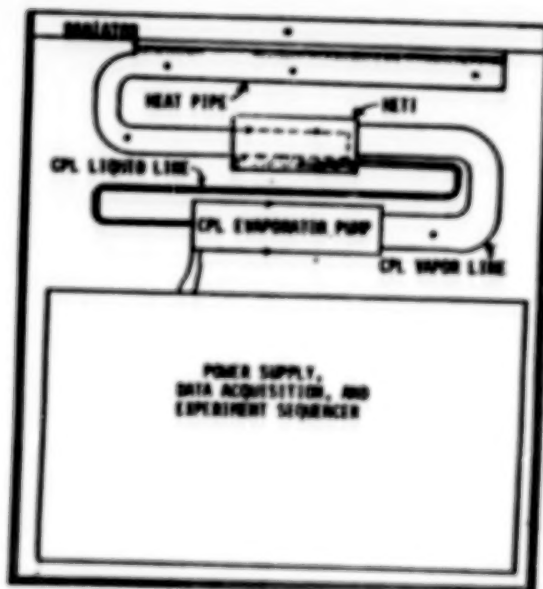
### A High-Efficiency Thermal Interface Between a Two-Phase Fluid Loop and a Heat Pipe Radiator

John A. Polner

TRW, Space and Technology Group

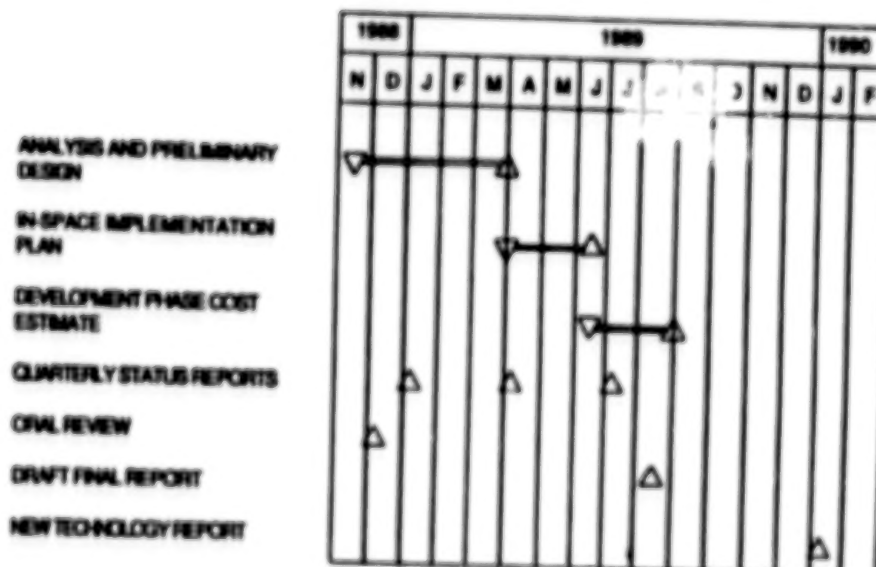
Contract: NAS5-30375, Goddard Space Flight Center, Roy McIntosh

## EXPERIMENT DESIGN



• THERMOCUPLE LOCATIONS

## SCHEDULE - EXPERIMENT DEFINITION PHASE



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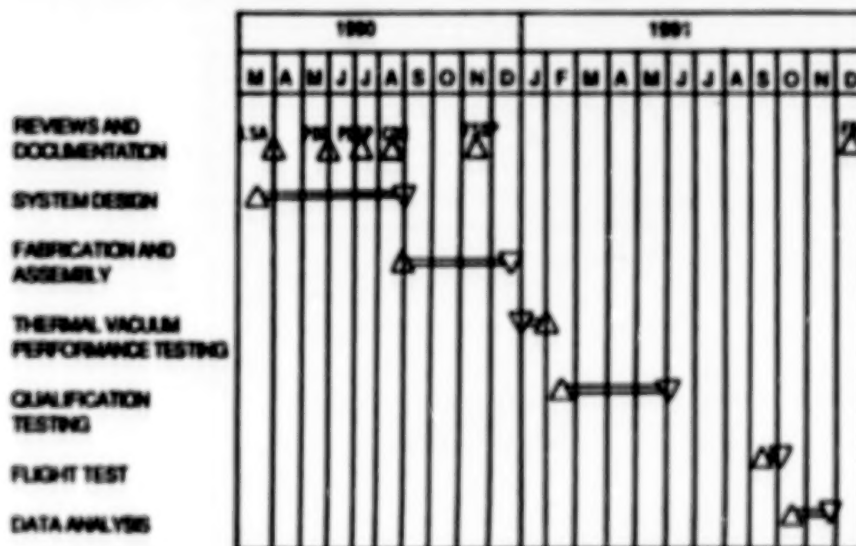
### *A High-Efficiency Thermal Interface Between a Two-Phase Fluid Loop and a Heat Pipe Radiator*

John A. Polmar

TRW, Space and Technology Group

Contract: NASS-30375, Goddard Space Flight Center, Roy McIntosh

## SCHEDULE - EXPERIMENT DEVELOPMENT PHASE



PDR - Preliminary Design Review  
LSA - Launch Services Agreement  
PSOP - Preliminary Safety Data Package  
FR - Final Report

CDR - Critical Design Review  
PSOP - Preliminary Safety Data Package  
QTR - Quarterly Report

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# POWER SYSTEMS AND THERMAL MANAGEMENT

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## Thermal Management

### *Moving Belt Radiator Dynamics*

W. Peter Teegan

Arthur D. Little, Inc.

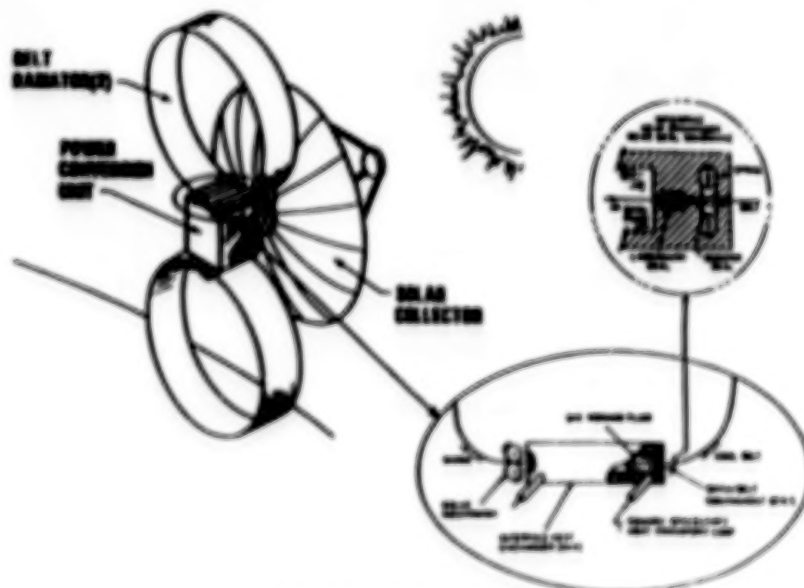
Contract: NAS3-25356, Lewis Research Center, Alan White

#### EXPERIMENTAL OBJECTIVE

Develop an improved understanding of the dynamics of a Moving Belt Radiator (MBR) during deployment and operation. In a zero gravity environment the primary forces on the belt will be those due to rotational motion (centrifugal forces) and spacecraft accelerations.

This understanding is needed to:

- Verify analytical methods developed to model the dynamics of flexible moving belt structures.
- Design MBR systems (belt structures, deployment, operation, and control)



LIQUID BELT RADIATOR CONCEPT

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**POWER SYSTEMS AND THERMAL MANAGEMENT**

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Thermal Management

***Moving Belt Radiator Dynamics***

W. Peter Teagan

Arthur D. Little, Inc.

Contract: NAS3-25358, Lewis Research Center, Alan White

**BACKGROUND/TECHNOLOGY NEED**

- Computerized dynamic models have been developed to describe shape of MBR as influenced by rotational speeds, acceleration fields, and belt structure
- Ground based testing subject to gravity are not very useful since gravity forces will dominate the centrifugal forces which define belt dynamics in a space environment
- Ground based zero-G experiments (drop towers, KC135 test plane) provide too short a test period for extensive testing
- Lack of an experimentally verified dynamic model adds uncertainty to the design of this class of radiator - possibly resulting in overly conservative design criteria

**EXPERIMENTAL DESCRIPTION**

- Experimental apparatus is a small scale moving belt structure 2-4 feet in diameter. Means are provided to:
  - vary belt rotational speed
  - subject belt to short term accelerations
  - vary sealing forces in interface heat exchanger structure
- Belt motion visualization (photographic) and measurements of forces on the IHX due to a belt motion, sealing pressure, and imposed acceleration will allow refinement of analytical models



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### Moving Belt Radiator Dynamics

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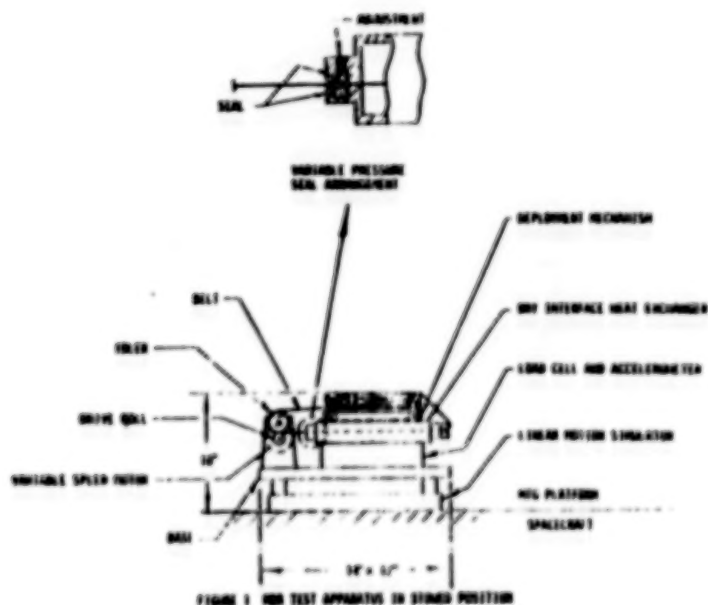


FIGURE 1 MBR TEST APPARATUS IN STOWED POSITION

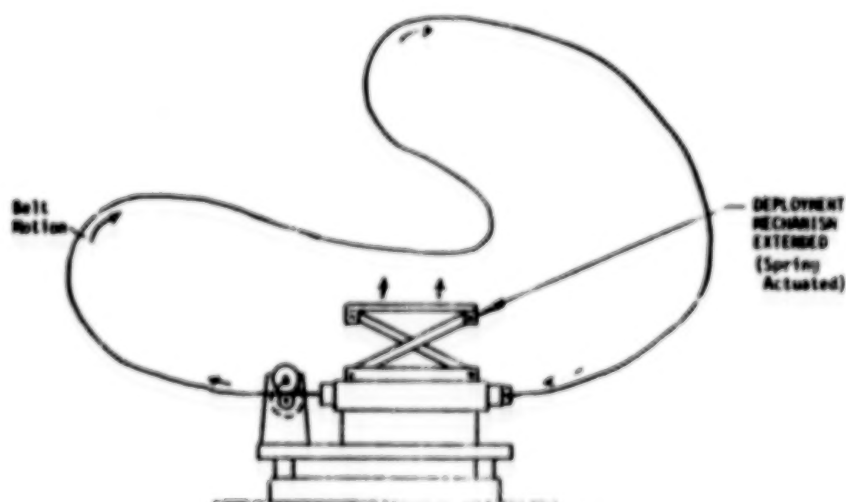


FIGURE 2 MBR SHAPE DURING DEPLOYMENT PROCESS

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*Moving Belt Radiator Dynamics*

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Contract: NAS3-25356, Lewis Research Center, Alan White

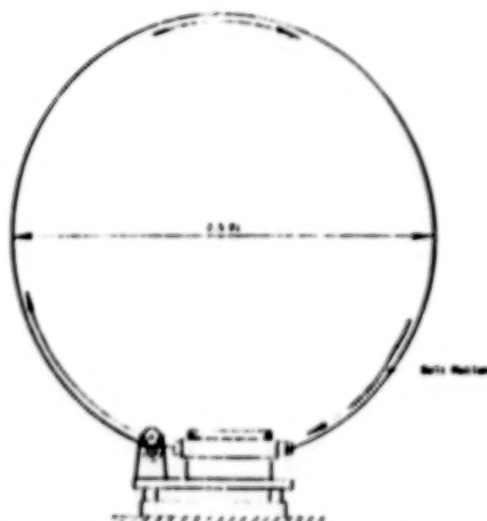


FIGURE 3 TEST APPARATUS DURING OPERATION (no perturbation)

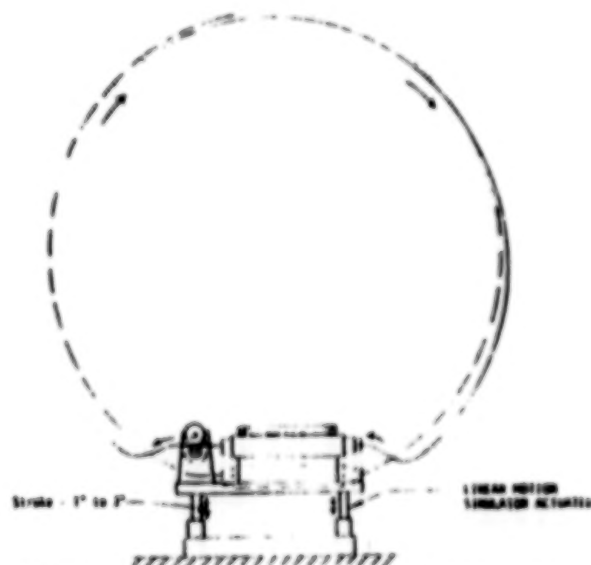


FIGURE 4 EXPERIMENTAL APPARATUS DURING LINEAR PERTURBATION

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**POWER SYSTEMS AND THERMAL MANAGEMENT**

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*Moving Belt Radiator Dynamics*

W. Peter Teagan

Arthur D. Little, Inc.

Contract: NAS3-25358, Lewis Research Center, Alan White

**PROJECT IS IN EXPERIMENTAL DEFINITION PHASE**



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## POWER SYSTEMS AND THERMAL MANAGEMENT

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Thermal Management

*Liquid Droplet Radiator*

Shomo L. Pfeiffer

Grumman Space Systems

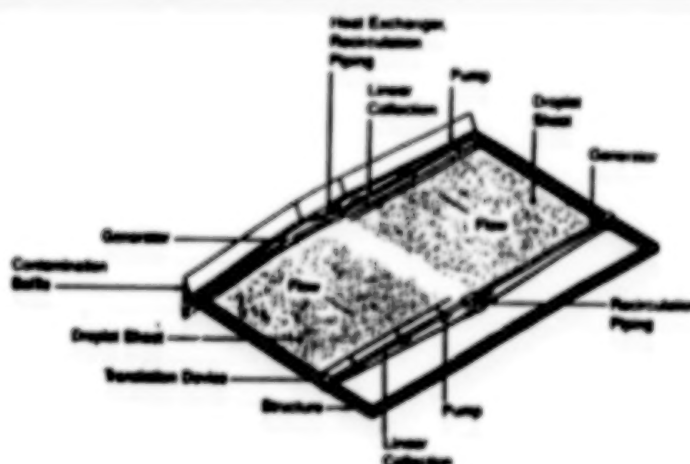
Contract: NAS3-25357, Lewis Research Center, Alan White

### Background

- Power levels for future space applications are increasing
- The heat rejection system can represent the dominant weight penalty of future space platforms
- Studies have shown that the Liquid Droplet Radiator (LDR) is significantly lighter than conventional radiators
- Contracts sponsored by NASA LeRC and AFAL have demonstrated LDR generator and collector operation

### Need

- Test subscale LDR system which will provide end-to-end system verification of the LDR concept in zero-g



- Heated fluid is generated into a spray of droplets
- Droplets radiatively cool as they pass through space
- Droplets are collected and recycled back to the heat source

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## POWER SYSTEMS AND THERMAL MANAGEMENT

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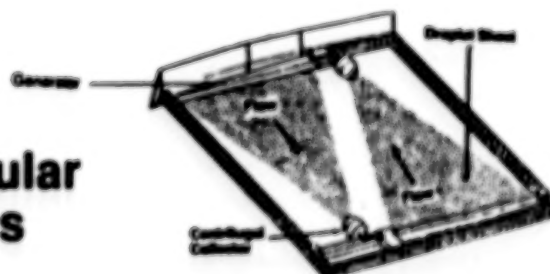
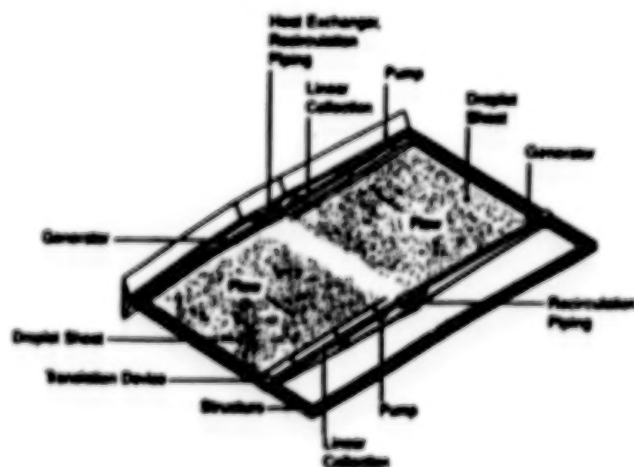
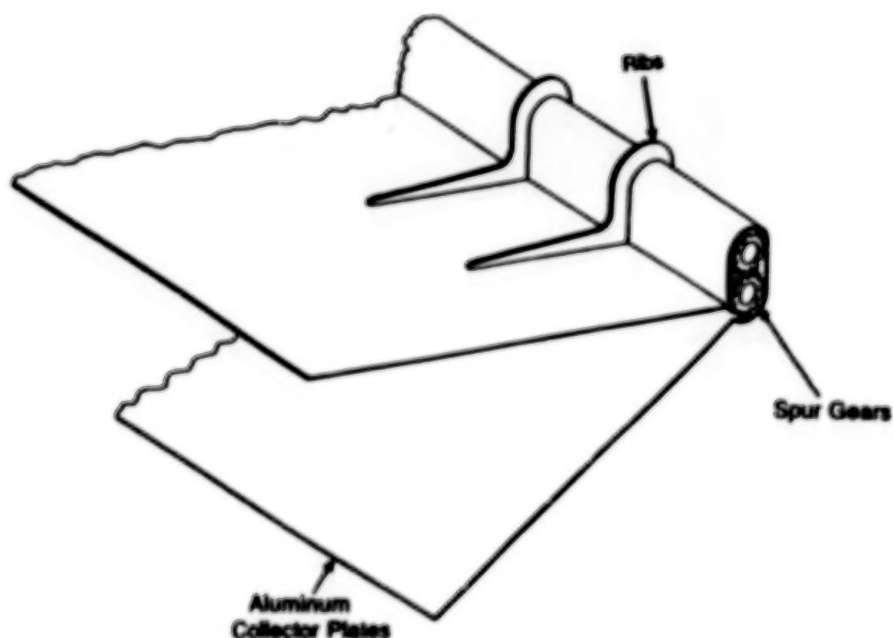
*Liquid Droplet Radiator*

Shomo L. Pfeiffer

Grumman Space Systems

Contract: NAS3-25357, Lewis Research Center, Alan White

### Conceptual Design of Linear Collector



### Rectangular and Triangular LDR Conceptual Designs



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## POWER SYSTEMS AND THERMAL MANAGEMENT

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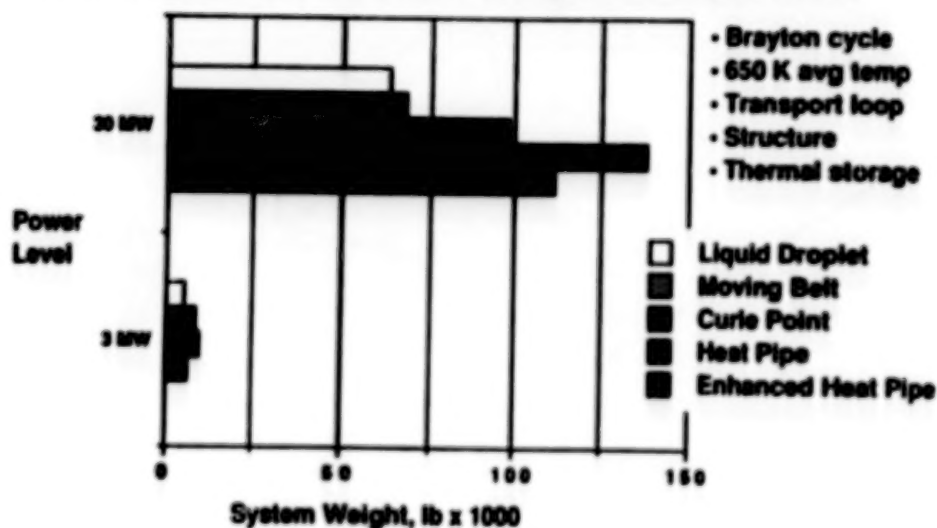
*Liquid Droplet Radiator*

Shlomo L. Pichler

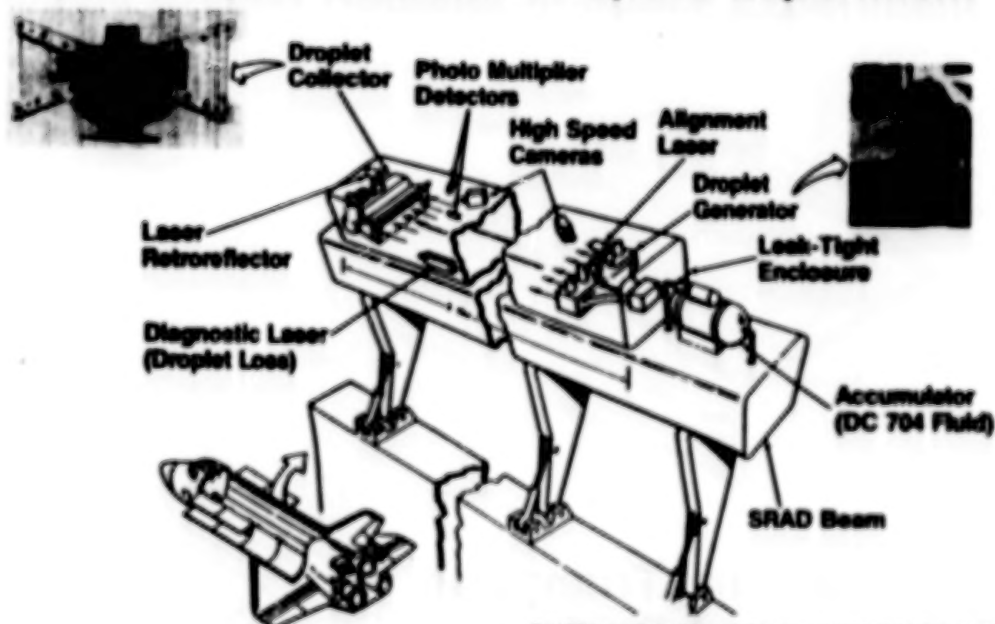
Grumman Space Systems

Contract: NAS3-25357, Lewis Research Center, Alan White

### Heat Rejection System Weight Comparison



### Liquid Droplet Radiator In-Space Experiment



LIQUID DROPLET RADIATOR (LDR)

The LDR is an advanced heat rejection concept which can be used to reject large amounts of heat using minimal weight. The heated fluid is generated into a spray of droplets which radiatively cool as they pass through space. The fluid is then collected and recycled back to the heat source.

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## POWER SYSTEMS AND THERMAL MANAGEMENT

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Thermal Management

Liquid Droplet Radiator

Shomo L. Pfeiffer

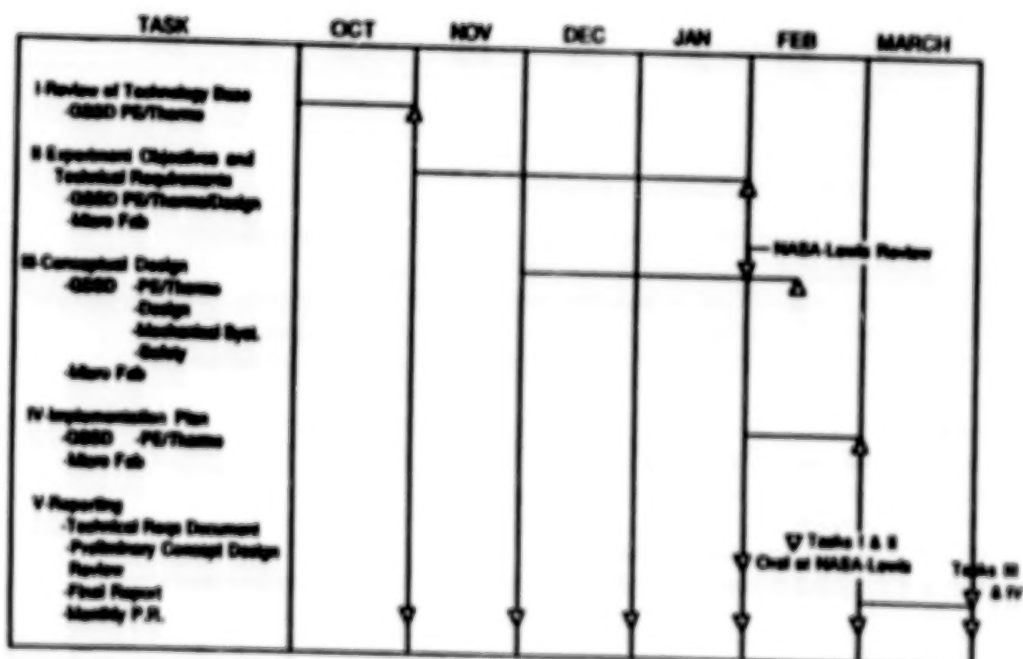
Grueman Space Systems

Contract: NAS3-25357, Lewis Research Center, Alan White

## Zero-g Experimental Objectives

- Startup
  - Generator fluid loss
  - Film/stream interaction at the collector
  - Initial film capture and pressurization
- Steady state running
  - Droplet stream characteristics
  - Generator/collector operation
- Shutdown
  - Effect of fluid decay on pump operation
  - Fluid losses at generator and collector

## Program Schedule



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**FLUID MANAGEMENT AND PROPULSION SYSTEMS**

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On-Orbit Fluid Management

**Tank Pressure Control Experiment**

M.D. Bents

Boeing Aerospace

Contract: NAS3-25383, Lewis Research Center, R. Kroll

**EXPERIMENT OBJECTIVE:**

Improve our understanding of jet mixing and its effect on thermal stratification, develop a better predictive capability, and give confidence in our ability to positively and reliably control cryogenic tank pressures in low gravity.

Our specific objectives are to:

- Measure heat and mass transfer rates and compare with models
- Observe mixing flow patterns to confirm/extend empirical correlations
- Obtain data to validate or improve NASA-ECLIPSE computer code
- Together with COLD-SAT experiment, show effects of tank scale and fluid properties on mixing

**BACKGROUND/TECHNOLOGY NEED**

**Justification:**

- Future space systems will require storage and transfer of cryogenic fluids
  - STV/OTV
  - manned Mars mission stage
  - Space Station nitrogen supply
  - satellite propellants, reactants, coolants
- Lack of natural convection in low-g leads to increased thermal stratification, higher tank pressures, and possibly longer no-vent fill times
- Use of refrigeration or TVS for pressure control depends on distribution of cooling in tank
- Compact forced-convection heat exchanger could save cost and weight
- Mixing energy should be minimized but must provide reliable pressure control

**Previous Work:**

- One-g thermal mixing tests
- Small-scale low-g dye mixing tests in drop tower
- Low-g simulations
- NASA-ECLIPSE code development
- In-space experiment needed to provide low-g data of sufficient duration and scale

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# FLUID MANAGEMENT AND PROPULSION SYSTEMS

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## On-Orbit Fluid Management

### Tank Pressure Control Experiment

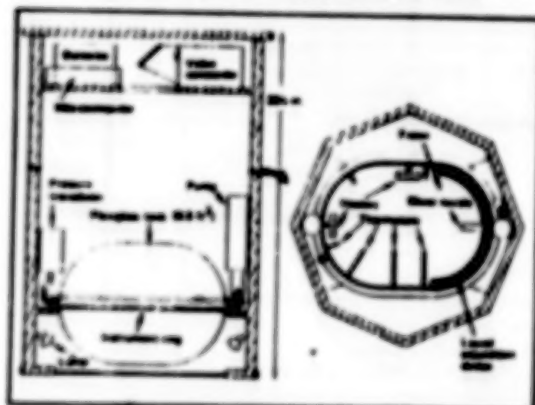
M.D. Benz

Boeing Aerospace

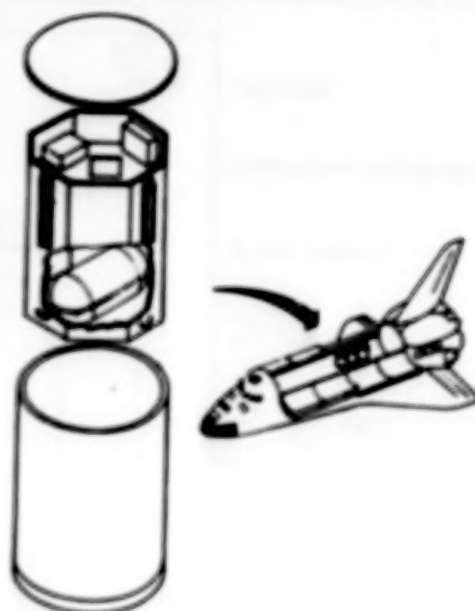
Contract: NAS3-25383, Lewis Research Center, R. Knoll

#### EXPERIMENT DESCRIPTION:

- Small Self-Contained Payload (GAS)
- 5.0 cu-ft., approx. 160 lbm
- autonomous control and data recording
- 800 W-hr power supply (alkaline cells)



Experiment Layout

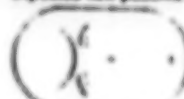


Payload Installation

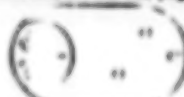
#### PROPOSED TESTS

- Measure effect of low-g on stratification buildup
- Measure performance of mixer as functions of flow rate and vapor location

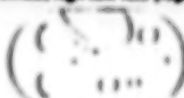
expected flow patterns:



symmetrical, low flow rate (regime I)



symmetrical, high flow rate (regime IV)



unsymmetrical, high flow rate

#### PROCEDURE

- Heat fluid at one of two locations
- Measure pressure rise rate and temperature gradients
- Mix contents at a range of flow rates and measure pressure collapse rate, temperature transients
- Record liquid/vapor orientations and flow patterns on video

#### END RESULTS

- Demonstrate effective pressure control
- Determine minimum mixing energy
- Understand effect of g-jitter on self-mixing
- Provide visual record of fluid behavior
- Validate or identify needed improvements to NASA-ECLIPSE and other models

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# FLUID MANAGEMENT AND PROPULSION SYSTEMS

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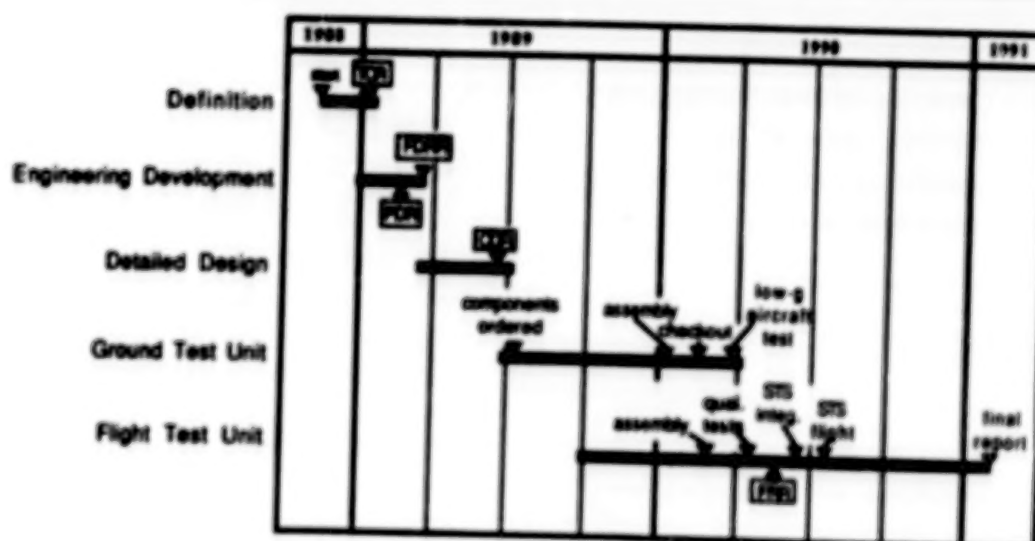
On-Orbit Fluid Management

*Tank Pressure Control Experiment*

M.D. Bentz

Boeing Aerospace

Contract: NAS3-25363, Lewis Research Center, R. Knoll



TCR: Technical Concept Review  
 PDR: Preliminary Design Review  
 FDRR: Flight Development Readiness Review  
 CDR: Critical Design Review  
 FRR: Flight Readiness Review



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**FLUID MANAGEMENT AND PROPULSION SYSTEMS**

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**On-Orbit Fluid Management**

***Integrated Cryogenic Experiment (ICE) Microsphere Insulation Investigation***

**Dean C. Reed**

**Lockheed Martin & Space Company, Research & Development Division**

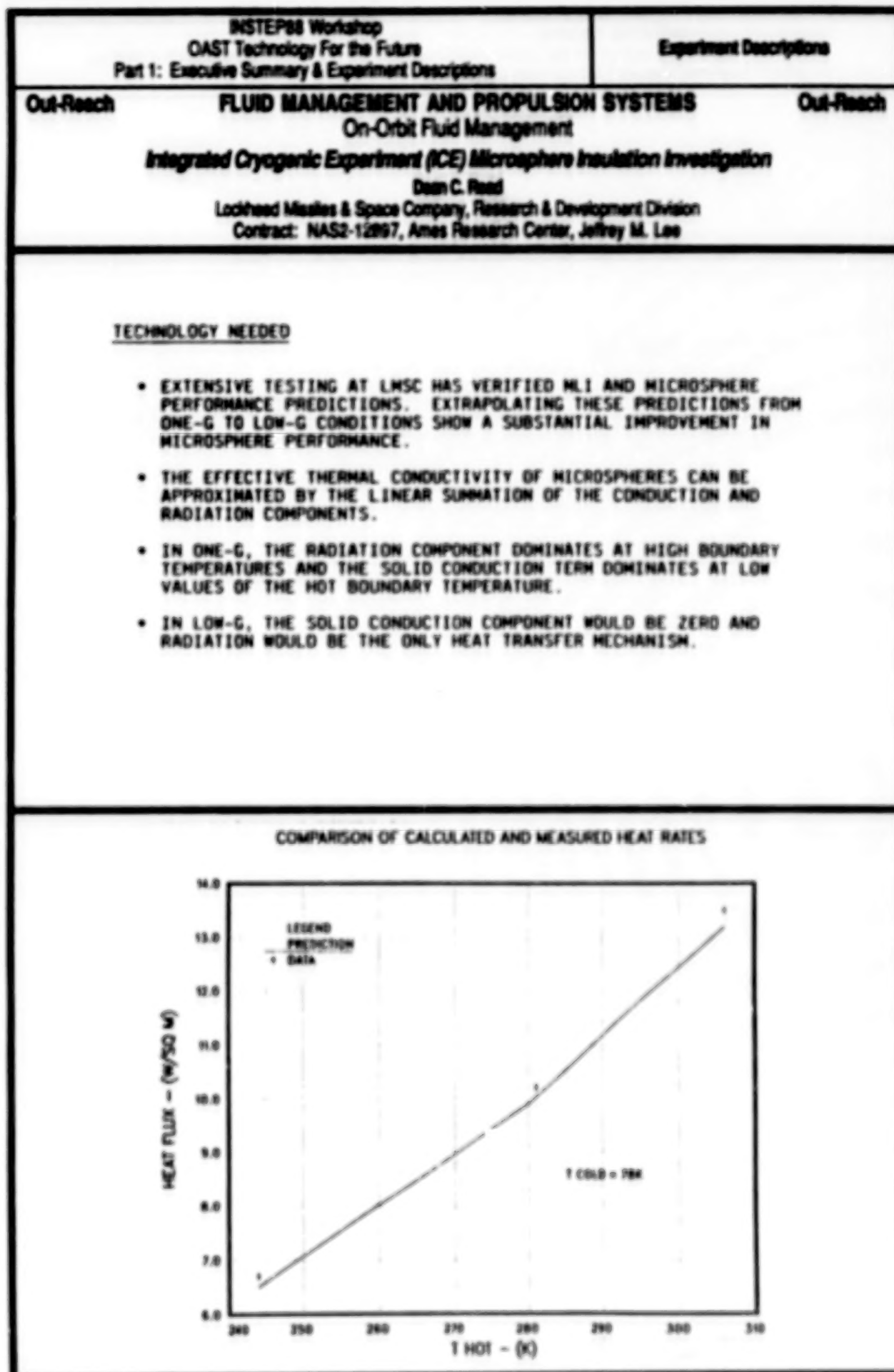
**Contract: NAS2-12897, Ames Research Center, Jeffrey M. Lee**

**EXPERIMENT OBJECTIVE**

- MEASURE THE LOW-G PERFORMANCE OF VARIOUS MICROSPHERE INSULATIONS OVER AN APPROPRIATE RANGE OF BOUNDARY TEMPERATURES. RESULTS OF PARTICULAR INTEREST ARE:
  - 1) COMPARISON OF ONE-G AND LOW-G PERFORMANCE
  - 2) PERFORMANCE AT LOW HOT BOUNDARY TEMPERATURES
  - 3) PERFORMANCE OF DIFFERENT TYPES OF MICROSPHERES
  - 4) COMPARISON TO MLI PERFORMANCE
- THE EXPERIMENT WILL BE MOUNTED IN THE INSTRUMENT WELL OF THE HELIUM EXTENDED LIFE DEWAR (HELD). USING THE HELD WILL ALLOW A CHARACTERIZATION OF THE DYNAMIC PROPERTIES OF THE PASSIVE ORBITAL DISCONNECT STRUT (PODS) SUPPORT SYSTEM UNDER LOW-G CONDITIONS.
- OTHER EXPERIMENTS MAY ALSO BE INCLUDED IN THE HELD.

**BACKGROUND**

- IMPROVED INSULATION SYSTEMS ARE OF GREAT INTEREST SINCE THEY ARE A MAJOR COMPONENT IN DETERMINING THE LIFETIME AND COST OF A CRYOGENIC SYSTEM.
- THE BENEFITS OF A MICROSPHERE INSULATION SYSTEM ARE:
  - 1) LOW-G PREDICTIONS SHOW THE POTENTIAL FOR BETTER PERFORMANCE THAN MLI.
  - 2) INSTALLATION OF MICROSPHERES IS LESS LABOR INTENSIVE THAN MLI, RESULTING IN A SUBSTANTIAL COST SAVINGS.
  - 3) POTENTIAL FOR BETTER PERFORMANCE WITH GEOMETRIES THAT ARE DIFFICULT TO WRAP WITH MLI.



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# FLUID MANAGEMENT AND PROPULSION SYSTEMS

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## On-Orbit Fluid Management

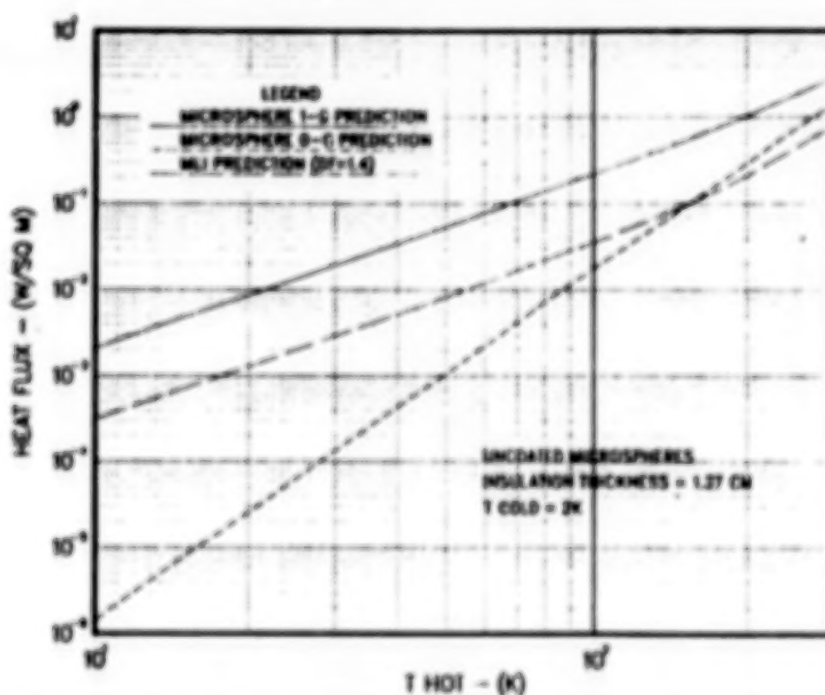
### *Integrated Cryogenic Experiment (ICE) Microsphere Insulation Investigation*

Dean C. Read

Lockheed Missiles & Space Company, Research & Development Division

Contract: NAS2-12897, Ames Research Center, Jeffrey M. Lee

#### COMPARISON OF MICROSPHERE AND MI PERFORMANCE PREDICTIONS



#### EXPERIMENT DESCRIPTION

- MICROSPHERE PARAMETERS TO BE TESTED INCLUDE DIAMETER, COATINGS, PACKING DENSITY, MIXES OF DIFFERENT MICROSPHERES, ETC.
- IF THE HEAT TRANSFER IS TOTALLY BY RADIATION, CHANGES IN THE HOT BOUNDARY TEMPERATURE WILL BE EASY TO DETECT FOR SMALL CHANGES IN HEATER POWER SINCE  $q \propto T^4$ .

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# FLUID MANAGEMENT AND PROPULSION SYSTEMS

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On-Orbit Fluid Management

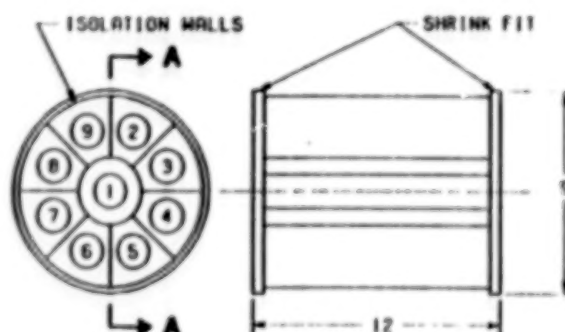
## Integrated Cryogenic Experiment (ICE) Microsphere Insulation Investigation

Dean C. Read

Lockheed Missiles & Space Company, Research & Development Division

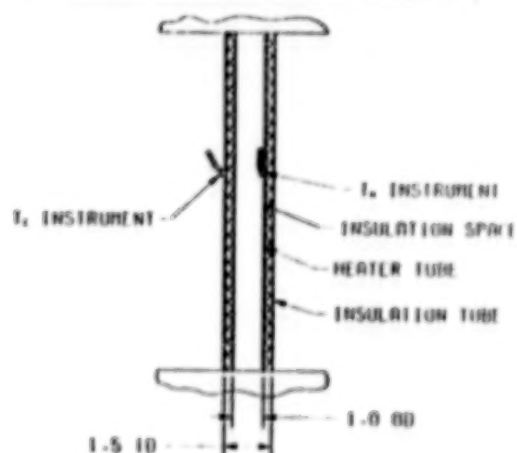
Contract: NAS2-12897, Ames Research Center, Jeffrey M. Lee

### EXPERIMENT CONFIGURATION

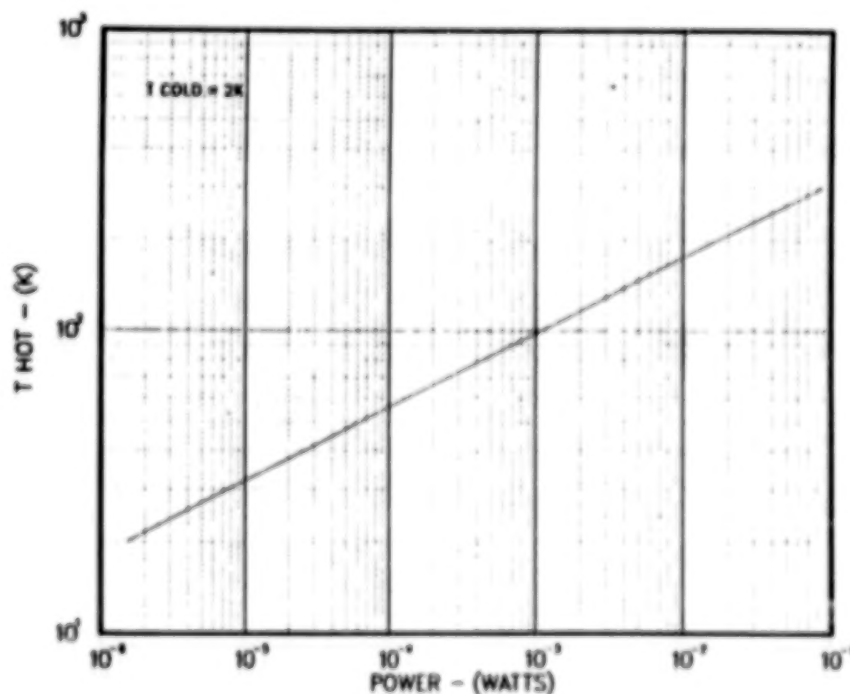


1 - REFERENCE INSULATION TUBE  
2 THRU 9 - MICROSPHERE TUBES

### INSULATION TUBE CONFIGURATION



### PREDICTED EXPERIMENTAL RESULTS



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# FLUID MANAGEMENT AND PROPULSION SYSTEMS

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On-Orbit Fluid Management

## Integrated Cryogenic Experiment (ICE) Microsphere Insulation Investigation

Dean C. Read

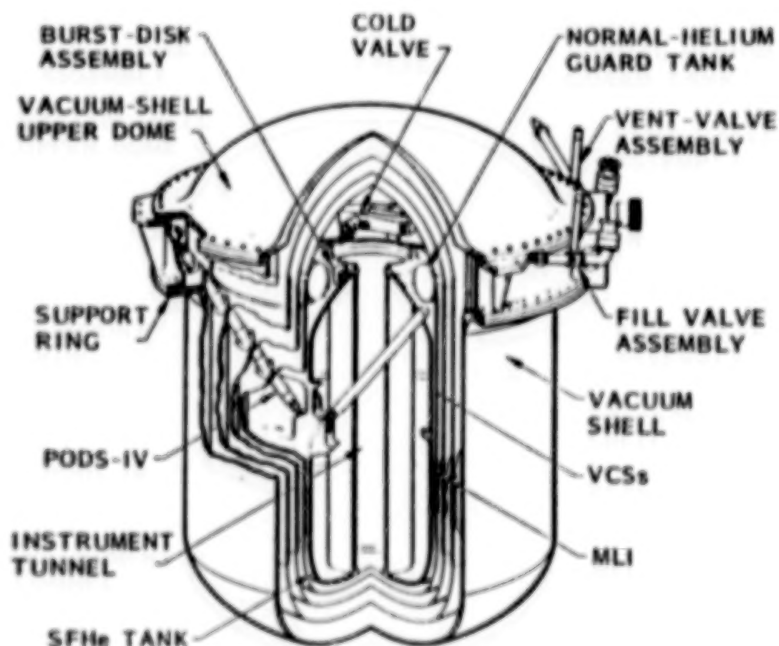
Lockheed Missiles & Space Company, Research & Development Division

Contract: NAS2-12897, Ames Research Center, Jeffrey M. Lee

### HELIUM EXTENDED LIFE DEWAR



### HELIUM EXTENDED LIFE DEWAR





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**FLUID MANAGEMENT AND PROPULSION SYSTEMS**

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On-Orbit Fluid Management

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Lockheed Missiles & Space Company, Research & Development Division

Contract: NAS2-12897, Ames Research Center, Jeffrey M. Lee

**MASTER SCHEDULE**

	YEAR QUARTER	1988				1989				1990				1991				1992			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
EXPERIMENT REQUIREMENTS & OBJECTIVES																					
PRELIMINARY DESIGN																					
PROJECT PLAN																					
EXPERIMENT ENGINEERING & DESIGN																					
FABRICATION & ASSEMBLY																					
TESTING & FLIGHT QUALIFICATION																					
PAYLOAD INTEGRATION & CHECKOUT																					
FIRST FLIGHT																					

INSTEP88 Workshop OAST Technology For the Future Part 1: Executive Summary & Experiment Descriptions		Experiment Descriptions
Out-Reach	<b>FLUID MANAGEMENT AND PROPULSION SYSTEMS</b> On-Orbit Fluid Management <i>Liquid Motion in a Rotating Tank</i> Franklin T. Dodge Southwest Research Institute Contract: NAS3-25358, Lewis Research Center, F.P. Chiaramonte	Out-Reach
<b>EXPERIMENT OBJECTIVE</b>  Develop a detailed understanding of liquid motions in a tank spinning about an external axis - primarily "inertial waves." Rotation rate can be so low that surface tension effects are important.  This understanding is needed for: <ul style="list-style-type: none"><li>• general scientific knowledge (many unanswered theoretical questions that cannot be resolved by ground-based testing)</li><li>• design of spinning spacecraft (attitude control and stability problems)</li></ul>		
<b>BACKGROUND / TECHNOLOGY NEED</b> <ul style="list-style-type: none"><li>• Basic theory still has unresolved questions. CFD codes have not yet proved applicable. Good data is needed to guide theoretical work.</li><li>• Ground-based fundamental experiments are practically impossible - spin rate must be large to eliminate gravitational effects. Observation and measurement under such conditions are practically impossible.</li><li>• Liquid torques and energy dissipation interfere with attitude control systems and can cause a "flat" spin for a "prolate" spinner.</li><li>• Lack of good models and data lead to overly conservative satellite design.</li></ul>		

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# FLUID MANAGEMENT AND PROPULSION SYSTEMS

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On-Orbit Fluid Management

## Liquid Motion in a Rotating Tank

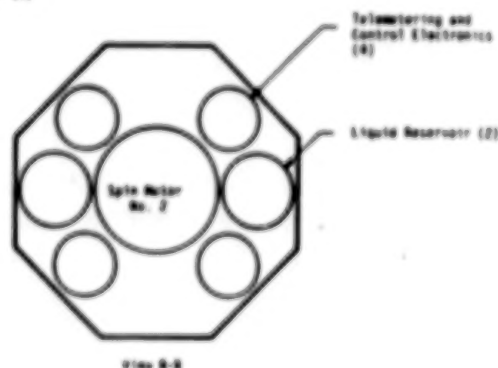
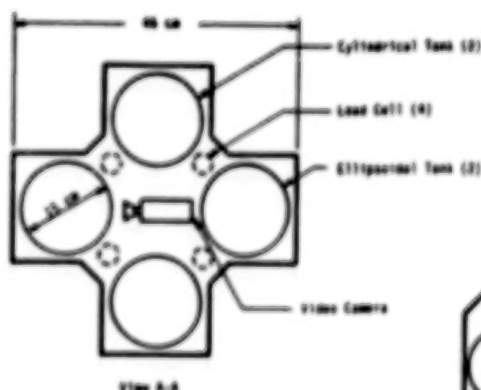
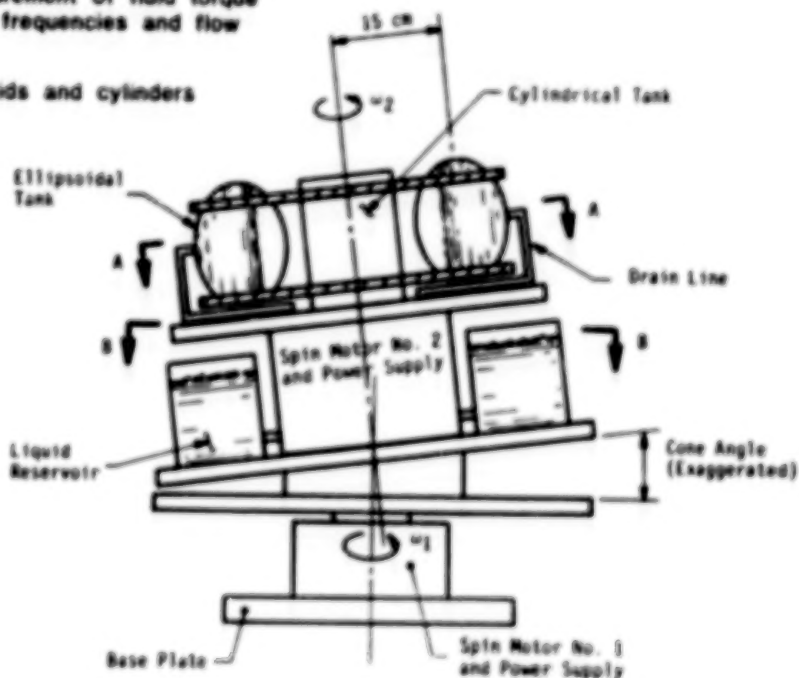
Franklin T. Dodge

Southwest Research Institute

Contract: NAS3-25358, Lewis Research Center, F.P. Chiaramonte

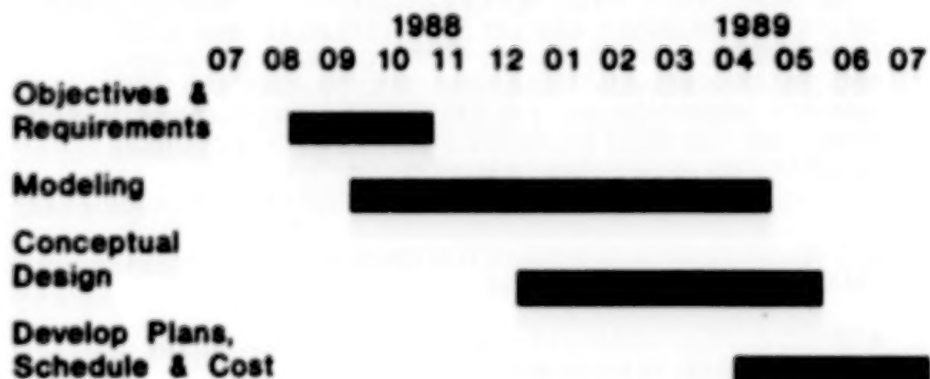
### EXPERIMENT DESCRIPTION

- Basic experimental apparatus is a forced motion spin table to control the motion of the test tanks
  - steady spin = 0 - 10 rpm
  - nutation (wobbling) frequency is less than twice the spin rate
- Flow visualization and measurement of fluid torque used to determine resonant frequencies and flow characteristics
- Two sets of tanks - ellipsoids and cylinders
  - 15 cm diameter



<b>Out-Reach</b>	<b>FLUID MANAGEMENT AND PROPULSION SYSTEMS</b> On-Orbit Fluid Management <i>Liquid Motion in a Rotating Tank</i> Franklin T. Dodge Southwest Research Institute Contract: NAS3-25358, Lewis Research Center, F.P. Chiaramonte	<b>Out-Reach</b>
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**PROJECT IS IN EXPERIMENT DEFINITION PHASE**



INSTEP88 Workshop OAST Technology For the Future Part 1: Executive Summary & Experiment Descriptions	Experiment Descriptions
Out-Reach	<div data-bbox="492 315 1149 349" data-label="Section-Header"> <h2>FLUID MANAGEMENT AND PROPULSION SYSTEMS</h2> </div> <div data-bbox="748 349 898 383" data-label="Text"> <p>Fluid Physics</p> </div> <div data-bbox="574 392 1077 423" data-label="Section-Header"> <h3><i>Thermoacoustic Convection Heat Transfer</i></h3> </div> <div data-bbox="721 430 923 461" data-label="Text"> <p>Prof. Masood Perang</p> </div> <div data-bbox="467 461 1174 492" data-label="Text"> <p>University of Tennessee, Mechanical &amp; Aerospace Engineering Department</p> </div> <div data-bbox="510 492 1133 519" data-label="Text"> <p>Contract: NAS3-25359, Lewis Research Center, Dr. An-Ti Chai</p> </div> <div data-bbox="1281 315 1417 347" data-label="Text"> <p>Out-Reach</p> </div>
<div data-bbox="386 607 710 640" data-label="Section-Header"> <h3><u>EXPERIMENT OBJECTIVE</u></h3> </div> <div data-bbox="384 663 1262 896" data-label="Text"> <p>THE OBJECTIVE IS TO ENHANCE FUNDAMENTAL UNDERSTANDING OF THERMOACOUSTIC CONVECTION (TAC) HEAT TRANSFER PHENOMENON AND EVALUATE ITS IMPORTANCE IN VARIOUS PROCESSES INVOLVING TRANSIENT HEAT TRANSFER IN LOW GRAVITY ENVIRONMENT. THE EXPERIMENT WILL PROVIDE DATA WHICH WILL BE USED TO VERIFY ANALYTICAL RESULTS AND COMPARE WITH GROUND-BASED EXPERIMENTS. THE UNDERSTANDING OF THIS PHENOMENON WILL BE APPLICABLE TO:</p> </div> <div data-bbox="384 920 1235 1153" data-label="List-Group"> <ul style="list-style-type: none"> <li>• DEVELOP INNOVATIVE WAYS FOR RAPID HEATING UNDER MICROGRAVITY CONDITIONS</li> <li>• IMPROVE HEAT TRANSFER CONTROL IN FLUID HANDLING, STORAGE AND TRANSPORT</li> <li>• UNDERSTAND THE ROLE AND IMPORTANCE OF HEAT TRANSFER IN ACOUSTIC LEVITATORS</li> </ul> </div>	
<div data-bbox="404 1361 607 1395" data-label="Section-Header"> <h3><u>BACKGROUND</u></h3> </div> <div data-bbox="422 1447 852 1478" data-label="Section-Header"> <h4>ANALYTICAL STUDIES INDICATE:</h4> </div> <div data-bbox="422 1534 1219 1621" data-label="List-Group"> <ul style="list-style-type: none"> <li>• VERY LARGE HEAT TRANSFER COMPARED TO CONDUCTION</li> <li>• VERY SMALL TRANSIENT TIME</li> </ul> </div> <div data-bbox="422 1702 847 1733" data-label="Section-Header"> <h4>EXPERIMENTAL STUDIES SHOW:</h4> </div> <div data-bbox="422 1787 1214 1908" data-label="List-Group"> <ul style="list-style-type: none"> <li>• CONTRADICTORY AND INCONCLUSIVE RESULTS</li> <li>• WHEN TAC EFFECTS ARE OBSERVED, THEIR IMPORTANCE IS SEEN TO BE NOT AS SIGNIFICANT</li> </ul> </div>	



Out-Reach

# FLUID MANAGEMENT AND PROPULSION SYSTEMS

Out-Reach

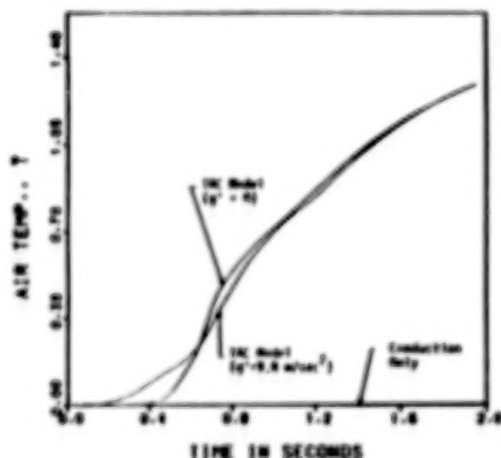
Fluid Physics

## Thermoacoustic Convection Heat Transfer

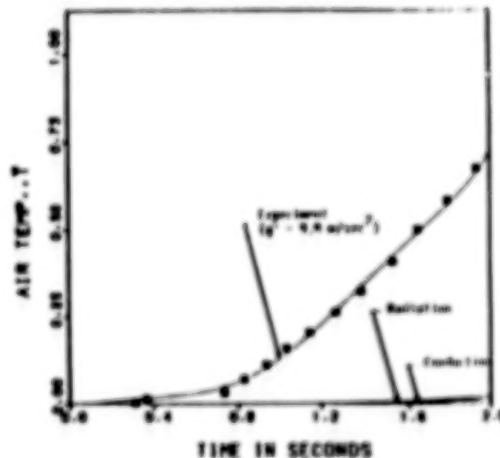
Prof. Masood Perang

University of Tennessee, Mechanical & Aerospace Engineering Department

Contract: NAS3-25351, Lewis Research Center, Dr. An-Ti Chai



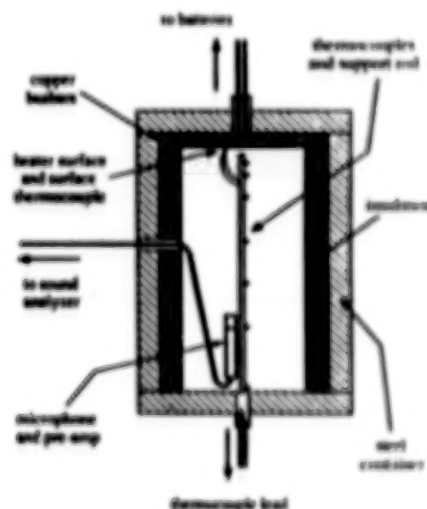
Comparison of the Results of the TAC Numerical Model with the Pure Conduction Solution



Comparison of the Numerical Results (Conduction and Radiation) and Experimental Results

### EXPERIMENT DESCRIPTION

THE APPARATUS WILL PROVIDE RAPID HEATING OF A COMPRESSIBLE FLUID NEAR A BOUNDARY. THE SYSTEM CAN BE MODIFIED TO PROVIDE EXPERIMENTAL DATA FOR BOTH CLOSED AND OPEN-ENDED VESSEL GEOMETRY. INSTRUMENTATION FOR TEMPERATURE AND PRESSURE MEASUREMENTS ARE REQUIRED TO DETECT AND RECORD THE EFFECTS OF THERMOCONVECTIVE WAVES.



Out-Reach

**AUTOMATION AND ROBOTICS**

Out-Reach

**Robotic Systems**

***Research and Design of Manipulator Flight Testbeds***

**T.M. Dephovich**

Martin Marietta Corporation, Astronautics Group

Contract: NAS9-17907, Johnson Space Center, Jerry Reuter

**EXPERIMENT OBJECTIVES**

Advance the state-of-the-art in space robotics through the design and development of manipulator testbeds to be flown on the Space Transportation System (STS) supporting:

- Rigid Link Manipulators
- Large, Flexible Manipulators

**BACKGROUND/TECHNOLOGY NEED**

- Significant results from ground experimentation have not been validated in space
- Space robotics R & D program has need for long-term testbed capability in support of:
  - Mechanisms
  - Sensors
  - Processing
  - Controls
- On-orbit experimentation is required to provide a database for defining technology directions

**EXPERIMENT DESCRIPTION**

- Experiment will support rigid and flexible arm experiments
- Processing system will support varied controls research objectives
- Experiment will support both autonomous and teleoperated functions
- Emphasis is on growth capability

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## AUTOMATION AND ROBOTICS

Out-Reach

### Robotic Systems

#### *Research and Design of Manipulator Flight Testbeds*

T.M. Delpovich

Martin Marietta Corporation, Astronautics Group  
Contract: NAS9-17907, Johnson Space Center, Jerry Reuter

#### SUMMARY

- A need exists for research testbeds, on orbit, to support validation of technology
- Must support both:
  - rigid and flexible structures
  - teleoperation and autonomy
  - operation from ground or space
- Key design feature: ability to integrate new technology

#### SCHEDULE

RESEARCH AND DESIGN	1988							1989			
MASTER SCHEDULE	J	J	A	S	O	N	D	J	F	M	A
FACE/OMACE											
Requirements Definition											
Concept Definition											
Program Definition											
Program Plan											

Out-Reach

**AUTOMATION AND ROBOTICS**  
**Robotic Systems**

Out-Reach

***Control of Flexible Robot Manipulators in Zero Gravity***

**Warren F. Phillips**

Utah State University, Center for Computer Aided Design and Manufacturing  
Contract: NAS8-37754, Marshall Space Flight Center, Pamela Nelson

**EXPERIMENT OBJECTIVE**

DEVELOP A MANIPULATOR CONTROL SYSTEM CAPABLE OF ACCURATELY CONTROLLING A ROBOT ARM WITH LIGHTWEIGHT NON-RIGID LINKS IN A ZERO GRAVITY VACUUM. THIS CONTROL SYSTEM MUST MEET THE FOLLOWING REQUIREMENTS:

- POSITION CONTROL OF THE END-EFFECTOR MUST BE AS GOOD AS OR BETTER THAN PRESENT DAY INDUSTRIAL ROBOTS.
- CONTROL ACCURACY MUST NOT BE A FUNCTION OF PAYLOAD MASS OVER THE DESIGN LOAD-RANGE.
- STRUCTURAL STIFFNESS OF THE MANIPULATOR LINKS MUST NOT SIGNIFICANTLY AFFECT THE POSITION CONTROL ACCURACY.

**BACKGROUND / TECHNOLOGY NEED**

PROBLEMS ASSOCIATED WITH USING A COMPLETE MODEL BASED, DECOUPLING AND LINEARIZING MANIPULATOR CONTROL SYSTEM:

- IT IS COMPUTATIONALLY VERY EXPENSIVE TO USE THE ENTIRE DYNAMIC MODEL INSIDE THE CONTROL LOOP.
- THE VALUES OF THE PARAMETERS IN THE DYNAMIC MODEL ARE OFTEN NOT ACCURATELY KNOWN.
- SOME OF THE PARAMETERS ARE NOT REPEATABLE BECAUSE THEY CHANGE AS THE ROBOT AGES.
- STRUCTURAL VIBRATIONS MAY BE INDUCED BY THE CONTROL SYSTEMS IN MANIPULATORS WITH FINITE STIFFNESS.

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## **AUTOMATION AND ROBOTICS**

Out-Reach

### **Robotic Systems**

#### ***Control of Flexible Robot Manipulators in Zero Gravity***

**Warren F. Phillips**

Utah State University, Center for Computer Aided Design and Manufacturing  
Contract: NAS8-37754, Marshall Space Flight Center, Pamela Nelson

### **BACKGROUND / TECHNOLOGY NEED**

#### **SIMPLIFICATIONS MADE IN MOST PRESENT DAY INDUSTRIAL ROBOT CONTROL SYSTEMS:**

- THE DYNAMIC MODEL IS NOT USED AT ALL INSIDE THE CONTROL LOOP.
- THE CONTROL SYSTEM GAINS ARE ALL SET TO CONSTANT DIAGONAL MATRICES.
- THE CONSTANT GAINS ARE SET AS HIGH AS POSSIBLE, SO THAT THE ERRORS CAUSED BY THE JOINT COUPLING WILL BE QUICKLY SUPPRESSED BY THE ERROR DRIVEN CONTROL LAW.
- ALL LINKS ARE CONSTRUCTED TO BE VERY STIFF, TO PREVENT THE HIGH GAINS FROM INDUCING STRUCTURAL VIBRATIONS.

### **BACKGROUND / TECHNOLOGY NEED**

#### **PROBLEMS ASSOCIATED WITH USING PRESENT INDUSTRIAL ROBOT CONTROL SYSTEMS FOR IN-SPACE APPLICATIONS:**

- IF THE MANIPULATOR IS DESIGNED TO HAVE VERY STIFF LINKS, IT NATURALLY MUST BE VERY HEAVY. A ROBOT TO PAYLOAD WEIGHT RATIO OF 50 IS COMMON.
- IF THE LINK WEIGHT AND STIFFNESS IS REDUCED, THE HIGH CONSTANT GAINS WILL EXCITE THE NATURAL VIBRATION MODES OF THE MANIPULATOR.
- IF THE CONSTANT GAINS ARE REDUCED, ERRORS INDUCED BY THE JOINT COUPLING WILL NOT BE ADEQUATELY SUPPRESSED.



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**AUTOMATION AND ROBOTICS**  
Robotic Systems

Out-Reach

***Control of Flexible Robot Manipulators in Zero Gravity***

Warren F. Phillips

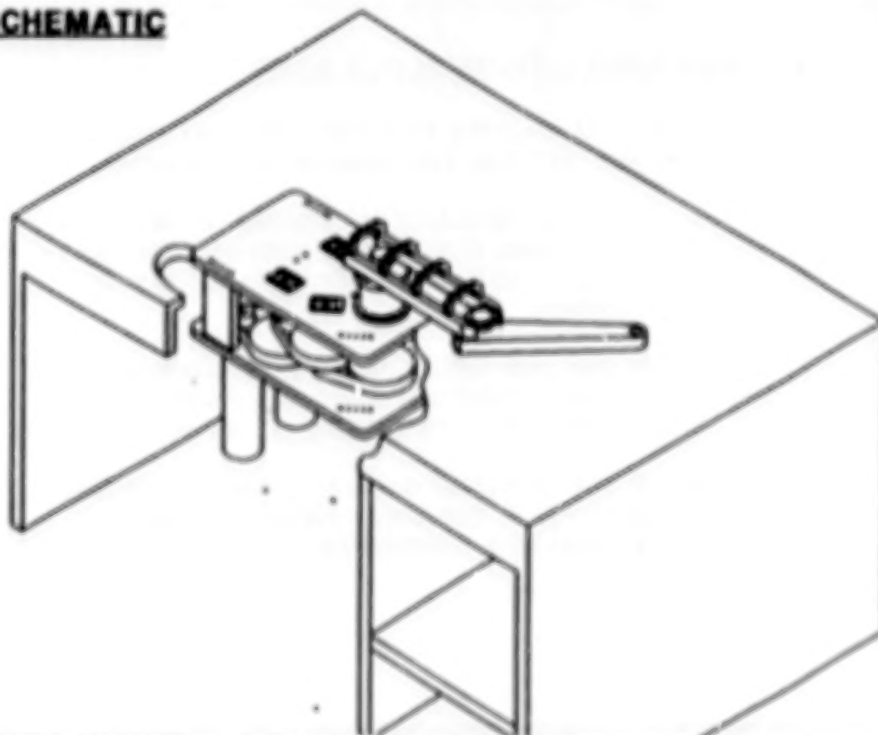
Utah State University, Center for Computer Aided Design and Manufacturing  
Contract: NAS8-37754, Marshall Space Flight Center, Pamela Nelson

**EXPERIMENT DESCRIPTION**

THE PRESENT RESEARCH WILL TEST THE FEASIBILITY OF ACCURATELY CONTROLLING A ROBOT ARM WITH LIGHTWEIGHT NON-RIGID LINKS IN A ZERO GRAVITY VACUUM. THE WORK WILL BE CARRIED OUT IN THREE PHASES:

- THE DEVELOPMENT OF A 2-AXIS ROBOT WHICH MINIMIZES THE EFFECTS OF GRAVITY AND CAN BE USED FOR PRELIMINARY GROUND TESTING OF THE CONTROL SYSTEM.
- THE DEVELOPMENT OF A COMPUTER SIMULATION FOR THE TEST ROBOT AND THE CONTROL SYSTEM.
- THE DEVELOPMENT OF A 3-AXIS ROBOT TO BE USED FOR IN-SPACE TESTING OF THE CONTROL SYSTEM.

**SCHEMATIC**



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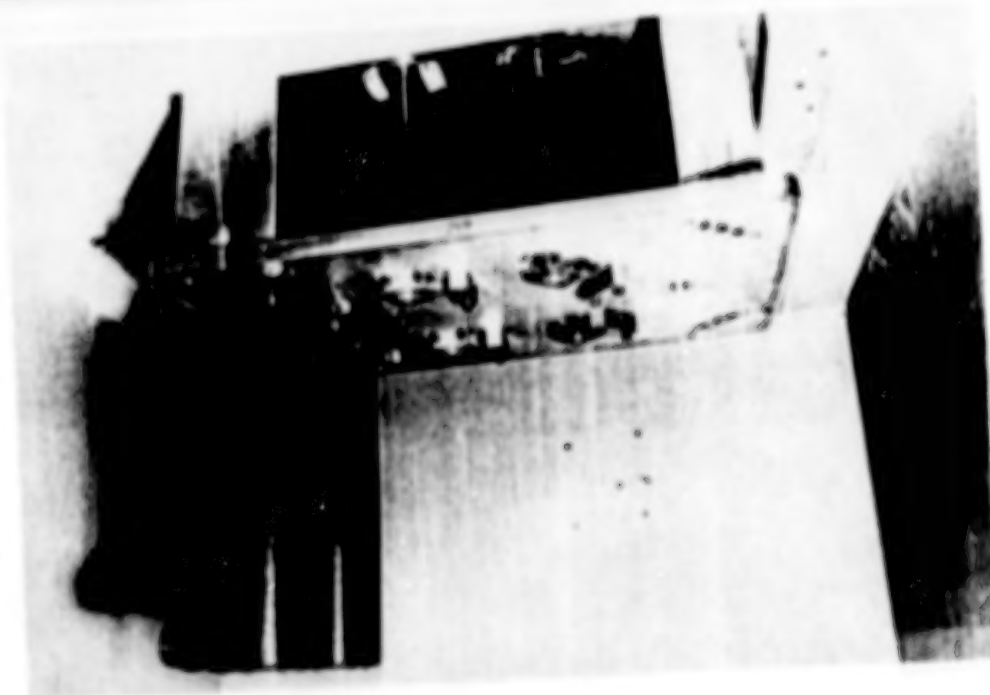
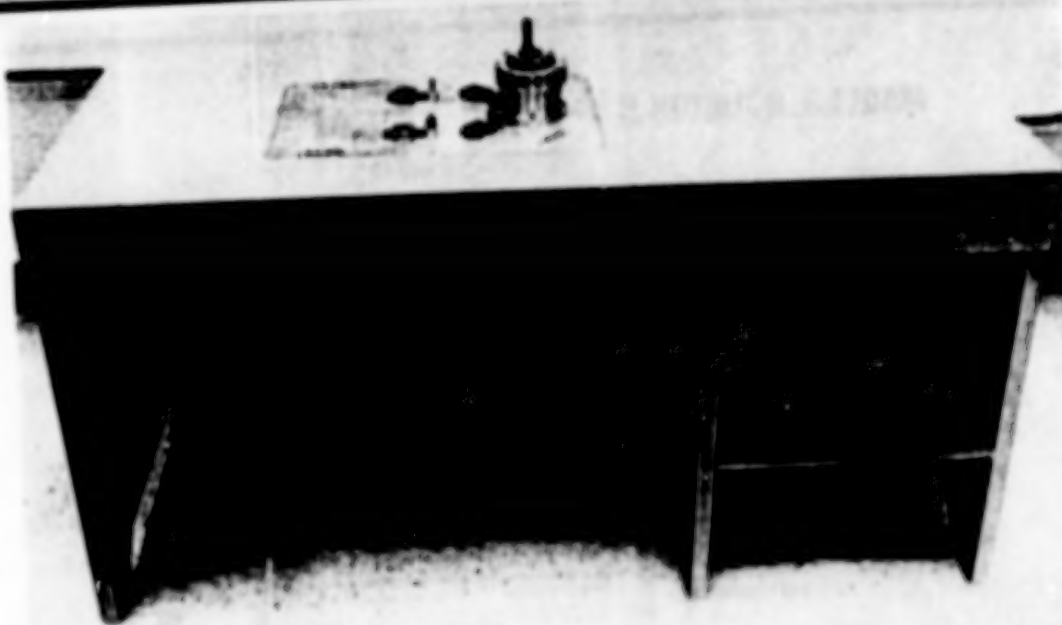
**AUTOMATION AND ROBOTICS**  
Robotic Systems

Out-Reach

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Out-Reach

# **AUTOMATION AND ROBOTICS**

Out-Reach

Robotic Systems

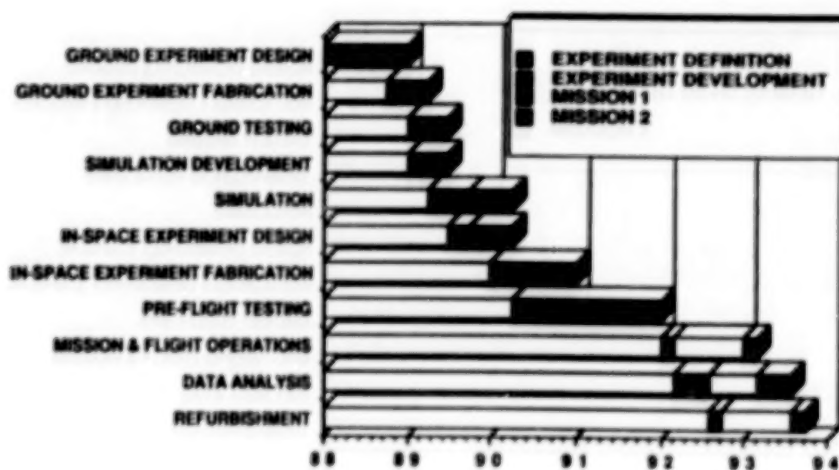
## ***Control of Flexible Robot Manipulators in Zero Gravity***

Warren F. Phillips

Utah State University, Center for Computer Aided Design and Manufacturing

Contract: NAS8-37754, Marshall Space Flight Center, Pamela Nelson

### **MASTER SCHEDULE**



Out-Reach

**AUTOMATION AND ROBOTICS**  
Robotic Systems (Control/Structure Interaction)  
*Jitter Suppression for Precision Space Structures*

Out-Reach

Robert M. Laurensen  
McDonnell Douglas

Contract: NAS1-18689, Langley Research Center / JPL, Dean W. Sparks, Jr. / John A. Garba

## EXPERIMENT OBJECTIVE

- **IN-SPACE DEMONSTRATION OF ACTIVE AND PASSIVE DAMPING TECHNIQUES TO SUPPRESS JITTER FOR PRECISION SPACE STRUCTURES**
- **IMPLEMENT A SHUTTLE PAYLOAD BAY EXPERIMENT TO ACCOUNT FOR IN-SPACE CONDITIONS**
- **ESTABLISH GROUND/FLIGHT DATABASE ON JITTER SUPPRESSION TECHNIQUES**

## BACKGROUND/TECHNOLOGY NEED

### • BACKGROUND

- SPACE-BASED OPTICAL APPLICATIONS REQUIRE LOW LINE-OF-SIGHT RESIDUAL JITTER LEVELS
- LASER COMMUNICATIONS AND LASER RADAR ARE REPRESENTATIVE SYSTEMS
- JITTER SUPPRESSION PLACES DEMANDS ON STRUCTURAL SUBSYSTEM
- PRESENT SYSTEMS - MICRORADIAN POINTING BUDGETS
- FUTURE SYSTEMS - SUB-MICRORADIAN POINTING AND/OR LARGER / COMPLEX CONFIGURATIONS

### • TECHNOLOGY NEED

- GROUND TEST VALIDATION IS INADEQUATE
- DATA NEEDED FOR LOW-G, THERMAL/VACUUM ENVIRONMENT OF SPACE
- PROVIDE VALIDATION OF JITTER SUPPRESSION TECHNIQUES FOR SPACE APPLICATION

Out-Reach

## AUTOMATION AND ROBOTICS

Out-Reach

Robotic Systems (Control/Structure Interaction)

### Jitter Suppression for Precision Space Structures

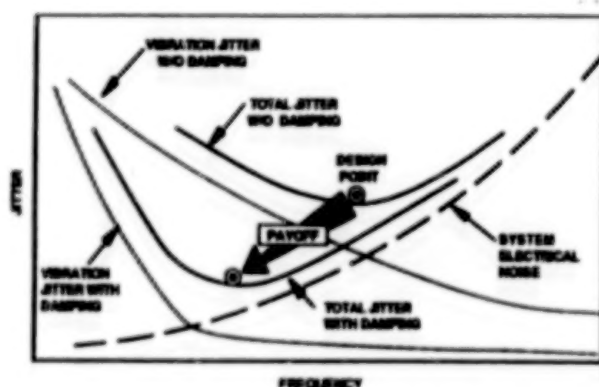
Robert M. Laurenceon

McDonnell Douglas

Contract: NAS1-18689, Langley Research Center / JPL, Dean W. Sparks, Jr. / John A. Garba

## REDUCED JITTER YIELDS SYSTEM PAYOFF

### REDUCED JITTER WITH DAMPING

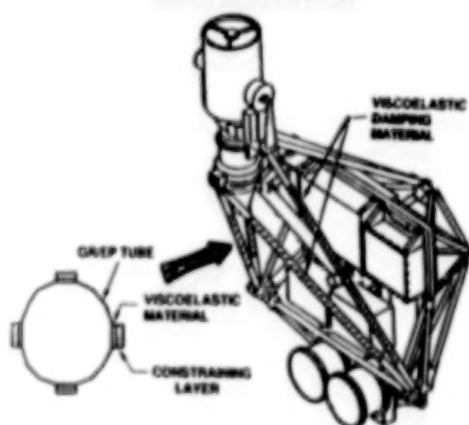


### SYSTEM PAYOFF

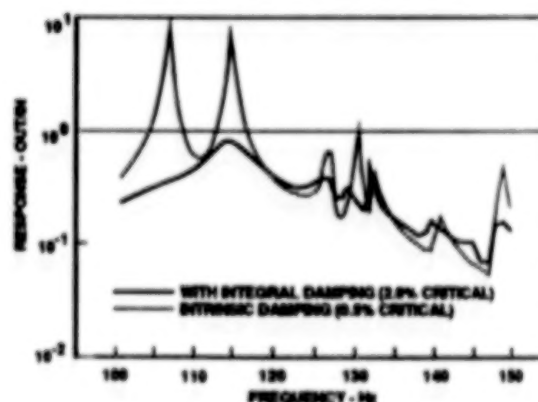
- REDUCED POWER
- REDUCED WEIGHT
- LOWER COST
- HIGHER RELIABILITY
- INCREASED LIFE

## ANALYSES DEMONSTRATE JITTER REDUCTION WITH INTEGRAL DAMPING

### VISCOELASTIC DAMPING MATERIAL IMPLEMENTATION



### JITTER ATTENUATION WITH VISCOELASTIC DAMPING



- ASSESSMENT OF PIEZOELECTRIC DAMPING
- EFFECTIVE MODAL DAMPING
- ORDER OF MAGNITUDE GREATER THAN VISCOELASTIC DAMPING



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**AUTOMATION AND ROBOTICS**  
Robotic Systems (Control/Structure Interaction)  
*Jitter Suppression for Precision Space Structures*

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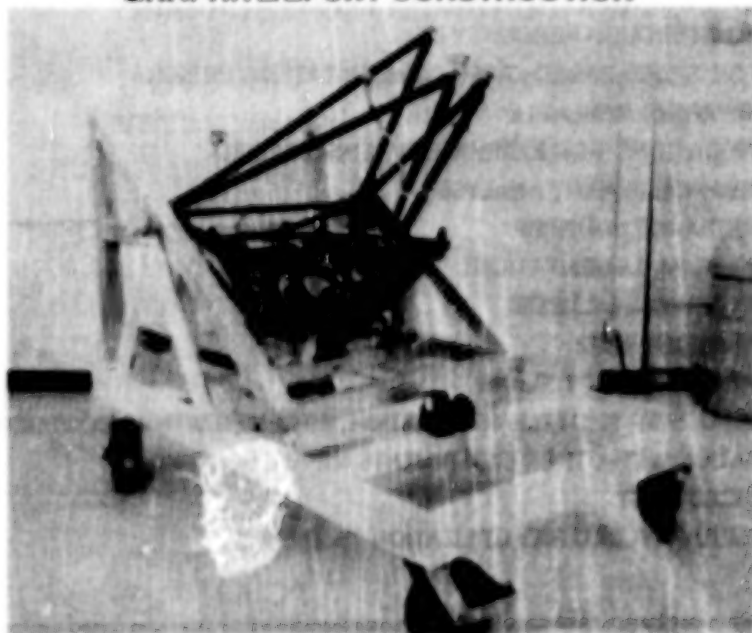
Robert M. Laurensen  
McDonnell Douglas

Contract: NAS1-18689, Langley Research Center / JPL, Dean W. Sparks, Jr. / John A. Garba

## EXPERIMENT DESCRIPTION

- **BASED ON EXISTING SPACE-BASED LASER COMMUNICATIONS SUBSYSTEM DESIGN**
- **USE EXISTING ENGINEERING MODEL HARDWARE**
  - **MASS SIMULATED EQUIPMENT COMPONENTS**
- **INTEGRATE DAMPING INTO GRAPHITE/EPOXY STRUCTURE**
  - **PASSIVE VISCOELASTIC DAMPING**
  - **ACTIVE PIEZOELECTRIC DAMPING**
- **PROVIDE EXCITATION SOURCES AND INSTRUMENTATION**
- **INTEGRATE INTO SHUTTLE PAYLOAD BAY EXPERIMENT**

## ENGINEERING MODEL UNIT STRUCTURE GRAPHITE/EPOXY CONSTRUCTION



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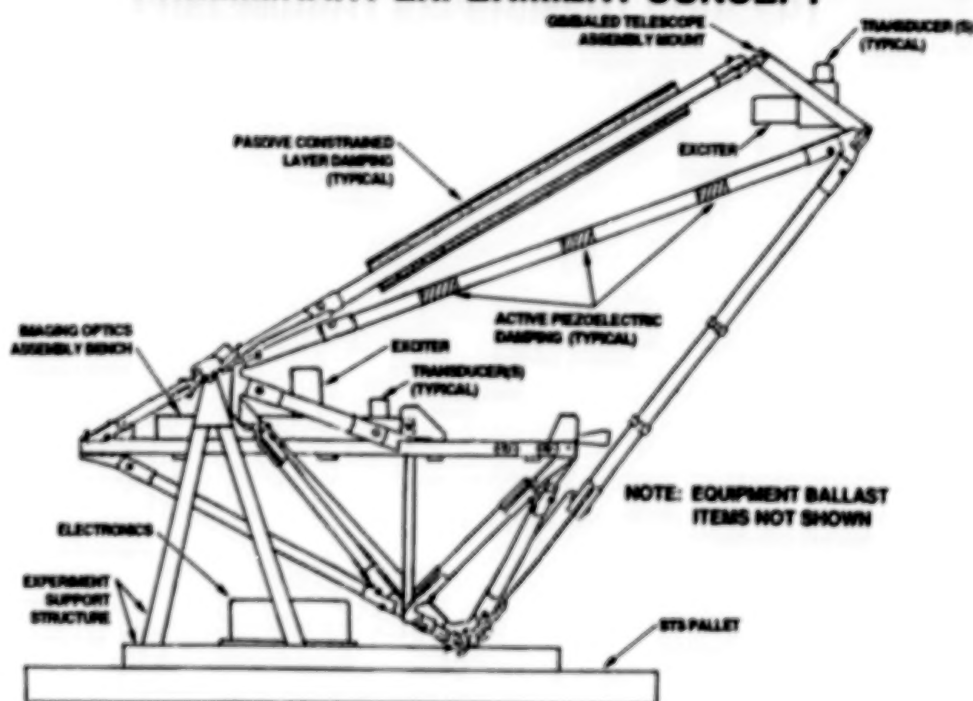
**AUTOMATION AND ROBOTICS**  
Robotic Systems (Control/Structure Interaction)  
*Jitter Suppression for Precision Space Structures*

Robert M. Laurensen

McDonnell Douglas

Contract: NAS1-18689, Langley Research Center / JPL, Dean W. Sparks, Jr. / John A. Garba

**PRELIMINARY EXPERIMENT CONCEPT**



**SUMMARY**

- EXPERIMENT DEFINITION PHASE
  - JUNE 88 THROUGH FEBRUARY 89
- BASED ON SPACE-BASED LASER COMMUNICATIONS DESIGN
  - HARDWARE IS AVAILABLE
  - MODIFICATIONS FOR EXPERIMENT BEING DEFINED
- PERFORM PRELIMINARY ANALYSES
  - DISTURBANCE SOURCES
  - DAMPING IMPLEMENTATION
  - SUPPORTING ANALYSES
  - INSTRUMENTATION
- DEVELOP PRELIMINARY PLANS
  - GROUND TEST, SHUTTLE INTEGRATION, IMPLEMENTATION (COST/SCHEDULE)
- INTEGRATION WITH OTHER EXPERIMENTS MAY BE BENEFICIAL
  - REDUCED COST
  - MAXIMUM PAYLOAD BAY UTILIZATION

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**AUTOMATION AND ROBOTICS**  
Robotic Systems

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***Passive Damping Augmentation for Space Manipulators***

Dr. Thomas E. Alberts

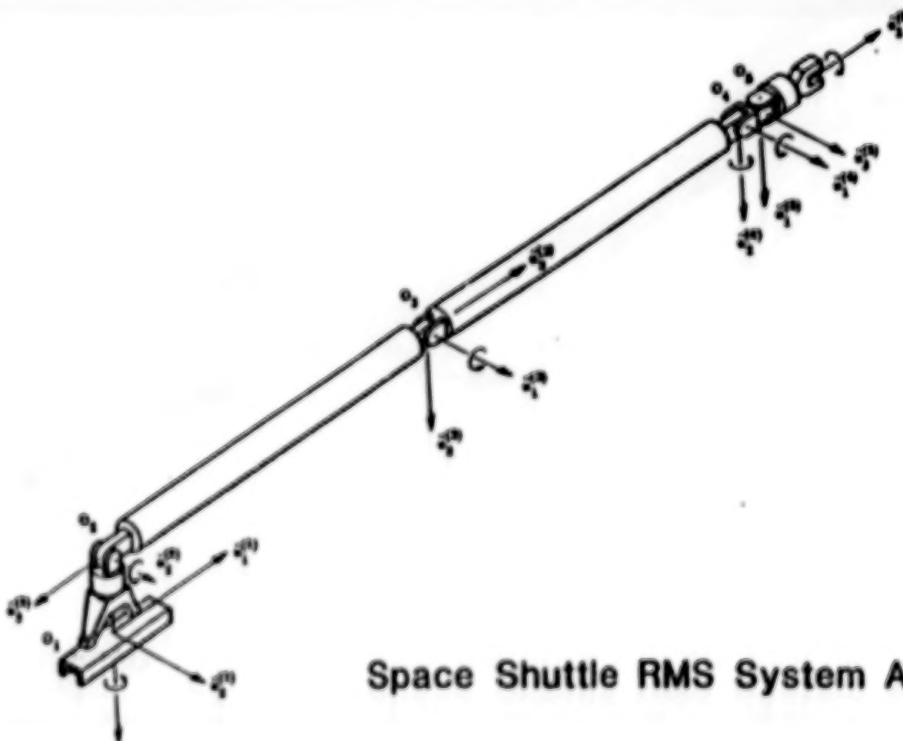
Old Dominion University (Support by 3M Corporation)

Contract: NAS1-18687, Langley Research Center, Jack Pennington

**EXPERIMENT OBJECTIVE**

Demonstrate the use of constrained layer viscoelastic damping treatments to reduce vibrations in flexible space manipulators. The target example is the space shuttle RMS. The current phase of the project includes:

- Analysis and design of damping treatment for bending and torsion.
- Design for reduced sensitivity to temperature variations.
- Simulate and evaluate results.
- Experimental verification.



Space Shuttle RMS System Assembly

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# **AUTOMATION AND ROBOTICS**

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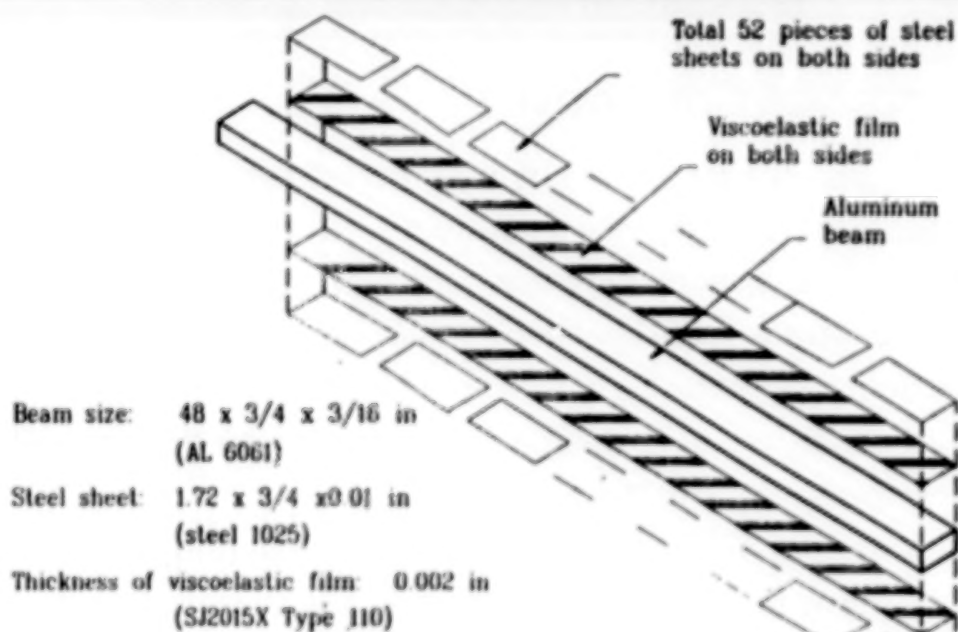
Robotic Systems

## ***Passive Damping Augmentation for Space Manipulators***

Dr. Thomas E. Alberts

Old Dominion University (Support by 3M Corporation)

Contract: NAS1-18687, Langley Research Center, Jack Pennington



## **DAMPING TREATMENT**



Finite Element Analysis of Damped System - Bending

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# **AUTOMATION AND ROBOTICS**

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Robotic Systems

*Passive Damping Augmentation for Space Manipulators*

Dr. Thomas E. Alberts

Old Dominion University (Support by 3M Corporation)

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**Finite Element Analysis of Damped System - Torsion**

Two beam element for  
 both sides steel sheets

Five QUA4 elements for  
 for aluminum beam

TRI FOR VISCO-  
 elastic to  
 connect the  
 gaps

Four TRI elements  
 for viscoelastic  
 material on gaps

Six QUA4 elements  
 for viscoelastic  
 material on both  
 side

**FINITE MESH FOR RECTANGULAR BEAM**



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**AUTOMATION AND ROBOTICS**

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Robotic Systems

*Passive Damping Augmentation for Space Manipulators*

Dr. Thomas E. Alberta

Old Dominion University (Support by 3M Corporation)

Contract: NAS1-18687, Langley Research Center, Jack Pennington

**DAMPING ANALYSIS**

- **Finite element analysis of single layer treatments.**
  - Bending**
  - Torsion**
  - Experiment**
- **Use validated code to evaluate multi-layer treatments designed to extend effective temperature range.**
- **Use damping results in full scale simulation.**

Out-Reach

## **SENSORS AND INFORMATION SYSTEMS**

Out-Reach

### **Sensors**

#### ***Development of Emulsion Chamber Technology***

**John Gregory**

University of Alabama in Huntsville

Contract: NAS8-37751, Marshall Space Flight Center, Jon Haussler

### **OBJECTIVES**

- DESIGN, FABRICATE AND FLY ON THE STS AN EMULSION CHAMBER OF THE GENERAL TYPE WHICH WILL BE A LIKELY CANDIDATE FOR COSMIC RAY AND HIGH ENERGY PHYSICS STUDIES ON THE SPACE STATION.
- ASSESS THE RADIATION BACKGROUND ENCOUNTERED IN SUCH DETECTORS IN ORBITS UP TO 400 km.
- ASSESS PRE- AND POST-FLIGHT ENVIRONMENTAL EFFECTS ON PASSIVE DETECTORS.
- ASSESS THE EFFECTS OF LARGE SHIELDING ON DOSE IN SPACE STATION ORBITS.
- PROVIDE THE ASTROPHYSICS COMMUNITY WITH AN ENVIRONMENTAL ASSESSMENT OF THE PERFORMANCE CAPABILITIES OF EMULSION TECHNIQUES IN SPACE.
- DEVELOP AND MODIFY EMULSION TECHNIQUES AS NECESSARY TO ALLOW OPTIMUM USE OF THE POWER OF THE METHOD.

### **BACKGROUND**

- NUCLEAR TRACK EMULSIONS HAVE BEEN USED FOR 50 YEARS IN PARTICLE PHYSICS AND COSMIC RAY PHYSICS AND HAVE PRODUCED MANY LANDMARK DISCOVERIES OR MEASUREMENTS:
  - FIRST DEMONSTRATION OF EXISTENCE OF  $\pi$ -MESON (1947).
  - DISCOVERY OF HEAVY ELEMENTS IN COSMIC RAYS (1948).
  - FIRST MEASUREMENT OF HELIUM SPECTRUM (1957).
  - CONFIRMATION OF TRANS-IRON NUCLEI IN COSMIC RAYS (1967).
  - OBSERVATION OF EVIDENCE OF QUARK-GLUON PLASMA FORMATION IN HEAVY NUCLEUS COLLISIONS ABOVE 1TeV/c.
  - FIRST MEASUREMENT OF CHEMICAL COMPOSITION OF COSMIC RAYS AT  $10^{14}$  eV.

Out-Reach

## SENSORS AND INFORMATION SYSTEMS

Out-Reach

### Sensors

#### *Development of Emulsion Chamber Technology*

John Gregory

University of Alabama in Huntsville

Contract: NAS8-37751, Marshall Space Flight Center, Jon Haussler

### TECHNOLOGY NEEDS

(TO BE ADDRESSED BY ENGINEERING FLIGHT OF EMULSION CHAMBER.)

- O RADIATION-INDUCED BACKGROUND IN ORBIT. SELF-SHIELDING TO AMBIENT RADIATION. SHOWER PRODUCTION WITHIN THE CHAMBER FROM ENERGETIC BACKGROUND RADIATION.
- O RADIATION-INDUCED BACKGROUND ACCUMULATED DURING STORAGE AND GROUND OPERATIONS.
- O TEMPERATURE AND HUMIDITY EFFECTS: IMPACT ON MECHANICAL DESIGN AND GROUND OPERATIONS. TEMPERATURE GRADIENT EFFECTS WITHIN THE CHAMBER.
- O ABILITY TO PERFORM VARIOUS MEASUREMENTS ON INTERACTIONS OBSERVED IN THE TEST FLIGHT CHAMBER WITH A KNOWN BACKGROUND.

### EXPERIMENT DESCRIPTION

- O DETECTOR PLATES INCLUDE NUCLEAR TRACK EMULSIONS OF DIFFERENT TYPES, X-RAY FILM AND CR-39 ETCHABLE TRACK DETECTORS. THIS STACK (ALSO INCLUDING INACTIVE MATERIAL SUCH AS LUCITE AND LEAD) MUST BE PROTECTED FROM LIGHT, HEAT, HUMIDITY AND VIBRATION DAMAGE.
- O THE STACK (OR EMULSION CHAMBER) IS CONTAINED IN A HERMETIC ALUMINUM BOX WHICH IS PARTIALLY EVACUATED. THE BOX HAS A HONEYCOMB LID TO REDUCE NUCLEAR INTERACTIONS OF INCOMING COSMIC RAYS.
- O DIMENSIONS: 50 CM X 60 CM X 40 CM
- O WEIGHT: 180 KG
- O TEMPERATURE:  $\leq 20^{\circ}\text{C}$ , REDLINE  $30^{\circ}\text{C}$
- O POWER: HEATERS, THERMISTORS AND TEMPERATURE DATA RECORDER
- O ORBIT:  $\leq 57^{\circ}\text{DEG}$ ;  $\leq 400\text{ KM}$ ; 5-10 DAYS

Out-Reach

# SENSORS AND INFORMATION SYSTEMS

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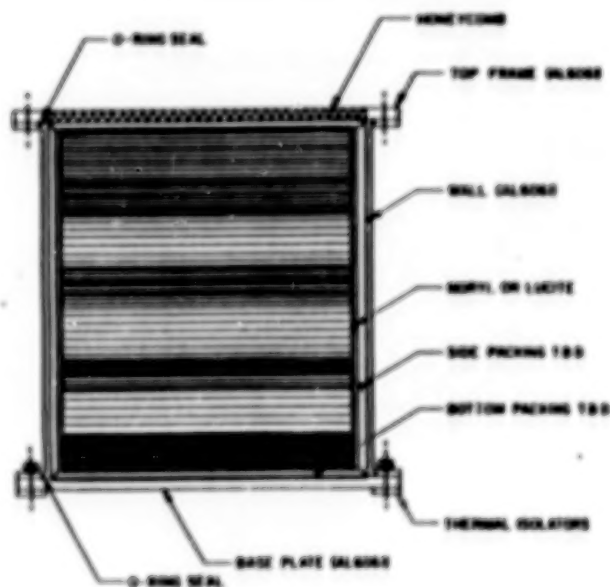
## Sensors

### Development of Emulsion Chamber Technology

John Gregory

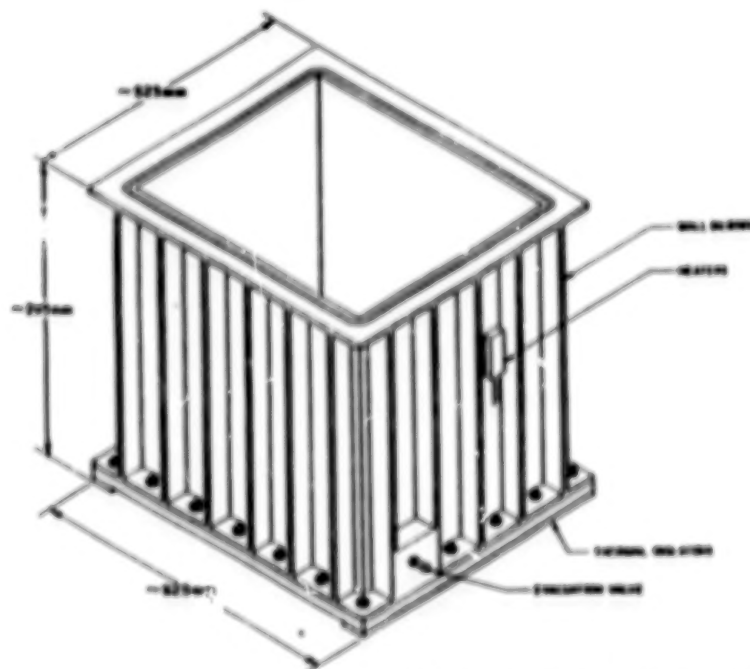
University of Alabama in Huntsville

Contract: NAS8-37751, Marshall Space Flight Center, Jon Hausler



--not to scale--

SECTION OF EMULSION CHAMBER AND CONTAINER



CONTAINER FOR EMULSION CHAMBER

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# **SENSORS AND INFORMATION SYSTEMS**

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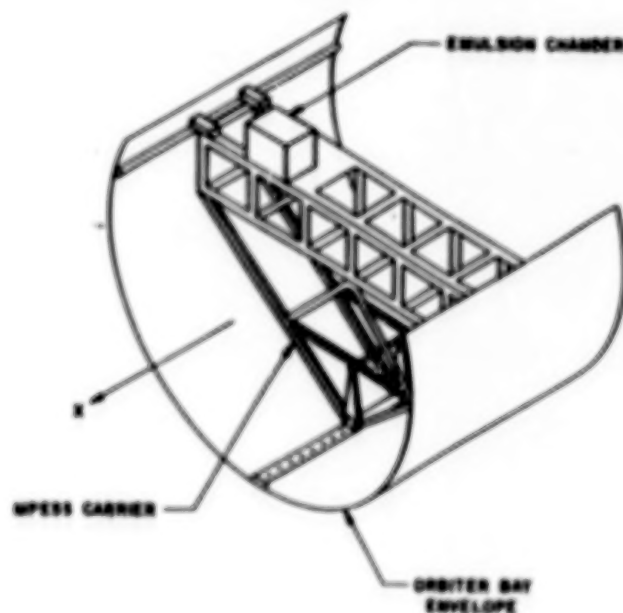
Sensors

## **Development of Emulsion Chamber Technology**

John Gregory

University of Alabama in Huntsville

Contract: NAS8-37751, Marshall Space Flight Center, Jon Haussler



### **SCHEDULE**

	6 MONTHS	12 MONTHS	18 MONTHS
0 DESIGN			
• MECHANICAL	_____		
• THERMAL	_____		
• SCIENTIFIC	_____		
0 MID-TERM REVIEW			
• MTRC	Δ		
0 FABRICATION OF TEST ARTICLE		_____	
0 PHASE B DESIGN REVIEW	..... Δ		
0 BACKGROUND STUDY	_____	_____	
0 PREPARATION OF DRAWINGS		_____	
0 DELIVERY OF DRAWINGS, SPECIFICATIONS AND COST PLAN FOR FLIGHT INVESTIGATION			Δ



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**SENSORS AND INFORMATION SYSTEMS**

Out-Reach

**Sensors**

***Infrared Focal Plane Performance in the South Atlantic Anomaly***

**Frank Junga**

Lockheed, Research and Development Division

Contract: NAS2-12898, Ames Research Center, Craig McCreight

**PROGRAM OBJECTIVES**

- Construct a model to predict selected focal plane performance parameters in the South Atlantic Anomaly environment. Outputs shall include proton-induced pulse height distribution in detectors and proton induced noise
- Verify pulse height distribution calculations for several proton energies and shielding thicknesses
- Develop a detailed concept for a flight experiment

**BACKGROUND**

- NASA and DOD will fly missions employing low background IR detectors. The proton environment can significantly affect detector performance

**TECHNOLOGY NEED**

- An accurate model is required to assess noise problems and to develop signal processing algorithms for noise reduction

**NEED FOR SPACE EXPERIMENT**

- We can model and verify model for effects of particle energy, geometric factors, and shielding. We cannot model noise contributions due to fluctuations in the instantaneous proton energy distribution.

Out-Reach

## **SENSORS AND INFORMATION SYSTEMS**

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### **Sensors**

#### ***Infrared Focal Plane Performance in the South Atlantic Anomaly***

**Frank Junga**

Lockheed, Research and Development Division

Contract: NAS2-12898, Ames Research Center, Craig McCreight

### **PULSE HEIGHT DISTRIBUTIONS, NOISE ANALYSIS, AND VERIFICATION**

#### **ANALYSIS INCLUDES**

Chord length distribution

Proton energy distribution

Proton energy loss, variance  
in energy distribution  
(a parameter)

Secondary sources of ionizing  
radiation (e.g. soft x-rays)

[NOVICE Code]

#### **VERIFICATION**

Measure pulse height  
distributions for various  
angles of incidence,  
proton energy (20-60 MeV),  
and type and thickness of  
shielding material

Test for blooming

#### **ACTIVITIES TO DATE**

- Background material assembled for pulse height distribution and noise calculations
- Visits to UC Berkeley and Davis cyclotrons to get specifics on experiment configurations
- Designed and fabricated necessary fixtures for proton pulse height distribution experiments\*
- Scheduled Davis cyclotron for Dec 7

\*NASA Ames completed dewar and software modifications

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## SENSORS AND INFORMATION SYSTEMS

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### Sensors

#### *Infrared Focal Plane Performance In the South Atlantic Anomaly*

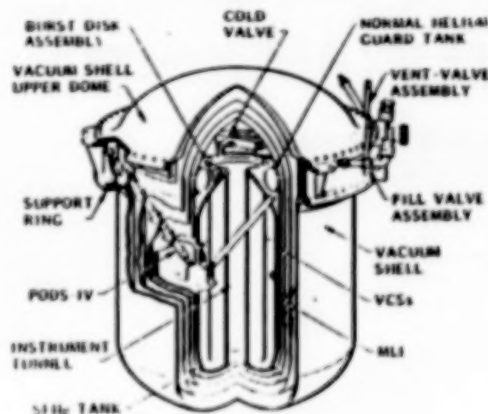
Frank Junga

Lockheed, Research and Development Division

Contract: NAS2-12898, Ames Research Center, Craig McCreight

### FLIGHT EXPERIMENT CONCEPT

#### Lockheed ID He Extended Life Dewar (HELD)



A self-contained experiment

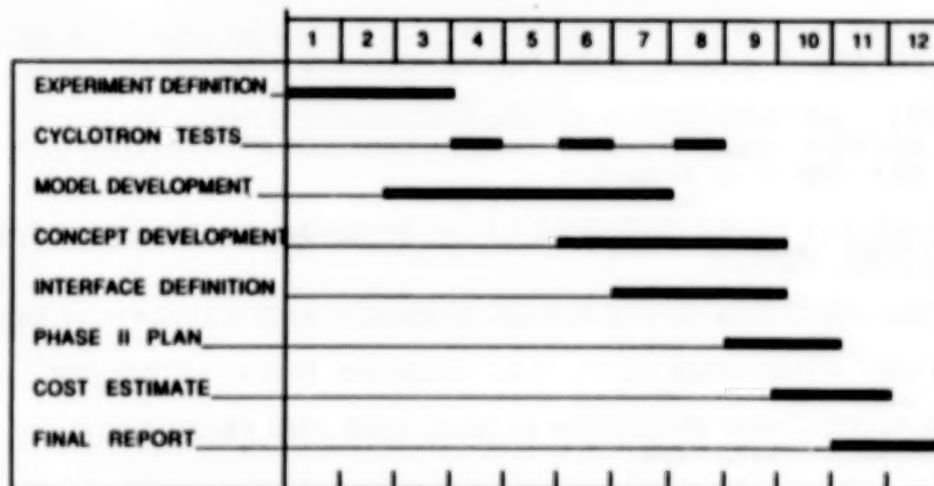
- Data collected on tape

Minimum of two focal plane arrays

- One with added shielding

Several experiments to be accommodated in dewar

### PROGRAM SCHEDULE (MONTHS AFTER GO-AHEAD)



Program Start Date: 7 September 1988

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**SENSORS AND INFORMATION SYSTEMS**

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Sensors

***Construction and In-Space Performance Evaluation of High-Stability Hydrogen Maser Clocks***

Robert F.C. Vessot

Smithsonian Astrophysical Observatory

Contract: NAS8-37752, Marshall Space Flight Center, Dr. R. Decher

**EXPERIMENT OBJECTIVE:**

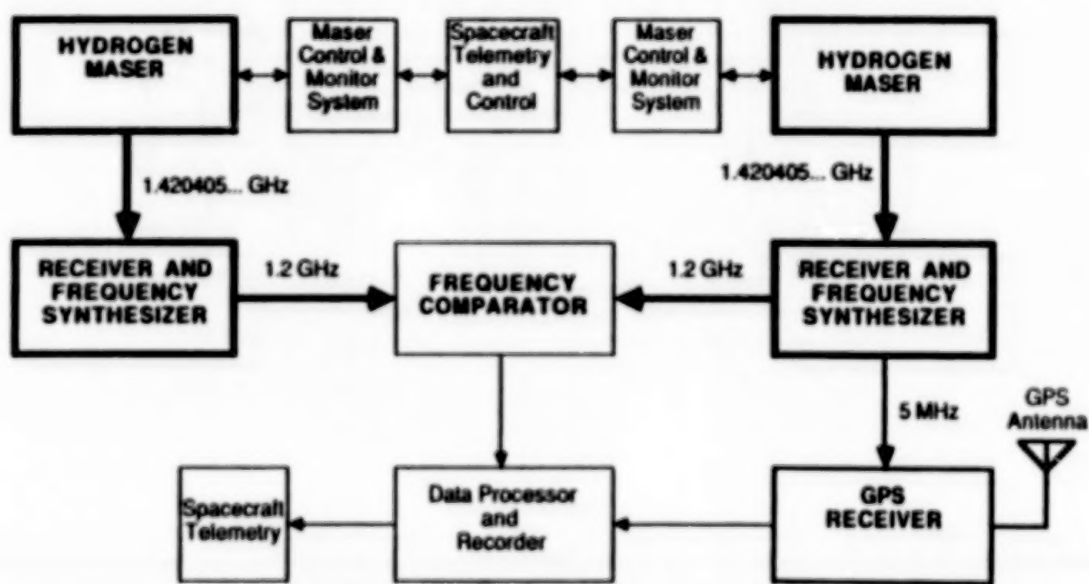
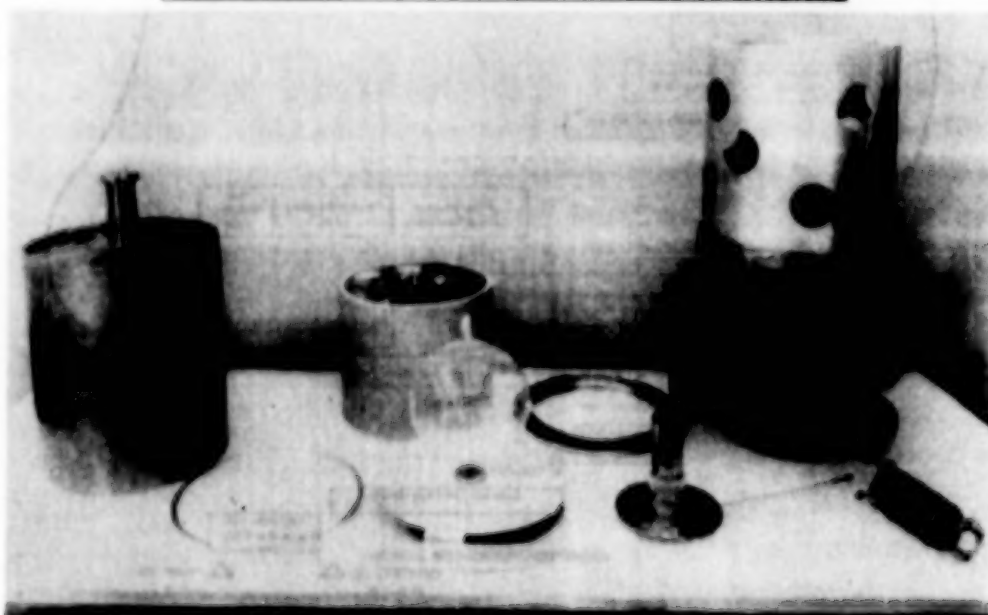
- TO DEVELOP TECHNOLOGY FOR ULTRASTABLE ATOMIC HYDROGEN MASER CLOCKS FOR LONG DURATION SPACE-BORNE EXPERIMENTS
- TO DESIGN AND BUILD TWO FLIGHT-QUALIFIED HYDROGEN MASERS
- TO TEST AND EVALUATE THE MASERS' PERFORMANCE IN SPACE

**BACKGROUND**

- 1976 GP-A (REDSHIFT) H-MASER DEVELOPED FOR SHORT DURATION ROCKET FLIGHT ~2 HOURS, MASER STABILITY  $7 \times 10^{-15}$
- 1980-84 STUDY OF ORBITING CLOCK EXPERIMENT FOR VERY HIGH PRECISION GLOBAL TIME AND FREQUENCY TRANSFER
- 1988 GROUND BASED MASER FREQUENCY STABILITY APPROACHING  $1 \times 10^{-16}$  AT  $10^4$  SEC; THIS CAN BE REALIZED IN A SPACEWORTHY H MASER

**TECHNOLOGY NEEDS SATISFIED BY SPACEBORNE ULTRA-HIGH STABILITY HYDROGEN MASERS**

- HIGH PRECISION SPACE-BORNE GUIDANCE AND NAVIGATION SYSTEMS
- RADIO ASTRONOMY VERY LONG BASELINE INTERFEROMETRY
- REAL-TIME HIGH PRECISION GLOBAL TIME AND FREQUENCY SYNCHRONIZATION
- GRAVITATION AND RELATIVITY PHYSICS
- SPACE-BORNE MULTISTATION TIME-CORRELATED RADAR TRACKING

INSTEP88 Workshop OAST Technology For the Future Part 1: Executive Summary & Experiment Descriptions		Experiment Descriptions
Out-Reach	<b>SENSORS AND INFORMATION SYSTEMS</b> Sensors	Out-Reach
<b>Construction and In-Space Performance Evaluation of High-Stability Hydrogen Maser Clocks</b> Robert F.C. Vessot Smithsonian Astrophysical Observatory Contract: NAS8-37752, Marshall Space Flight Center, Dr. R. Decher		
<b>EXPERIMENT DESCRIPTION</b>		
 <pre>graph TD     HM1[HYDROGEN MASER] &lt;--&gt; MCM1[Maser Control &amp; Monitor System]     MCM1 &lt;--&gt; STC[Spacecraft Telemetry and Control]     STC &lt;--&gt; MCM2[Maser Control &amp; Monitor System]     MCM2 &lt;--&gt; HM2[HYDROGEN MASER]     HM1 -- "1.420405... GHz" --&gt; RFS1[RECEIVER AND FREQUENCY SYNTHESIZER]     HM2 -- "1.420405... GHz" --&gt; RFS2[RECEIVER AND FREQUENCY SYNTHESIZER]     RFS1 -- "1.2 GHz" --&gt; FC[FREQUENCY COMPARATOR]     RFS2 -- "1.2 GHz" --&gt; FC     FC --&gt; DPR[Data Processor and Recorder]     DPR --&gt; ST[Spacecraft Telemetry]     RFS2 -- "5 MHz" --&gt; GR[GPS RECEIVER]     GR --&gt; DPR     GR --- GA[GPS Antenna]</pre>		
<b>PHOTOGRAPH OF SPACE MASER COMPONENTS</b>		
		



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# SENSORS AND INFORMATION SYSTEMS

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## Sensors

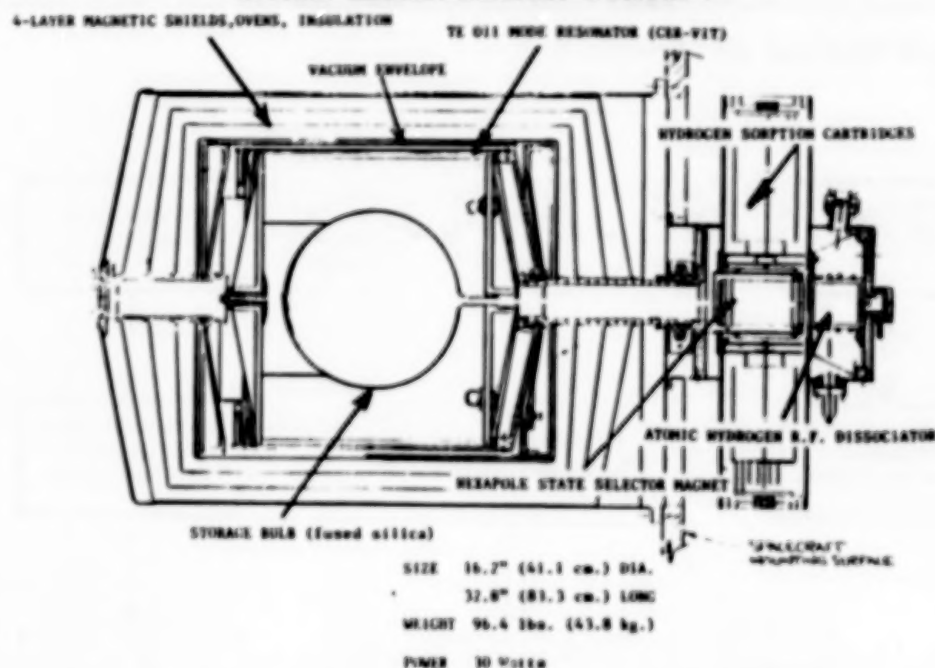
### Construction and In-Space Performance Evaluation of High-Stability Hydrogen Maser Clocks

Robert F.C. Vessiot

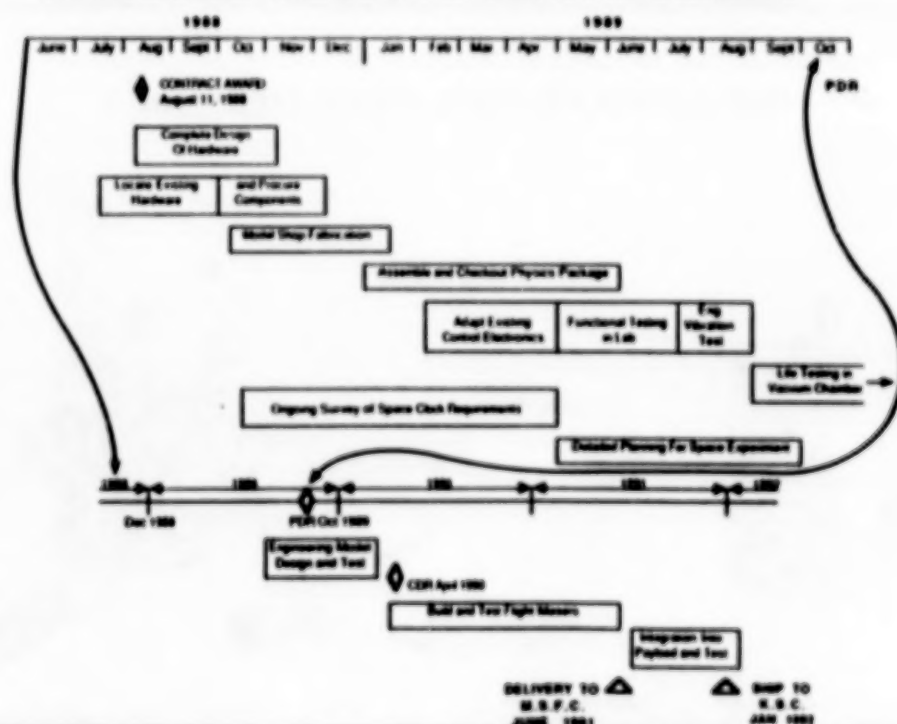
Smithsonian Astrophysical Observatory

Contract: NAS8-37752, Marshall Space Flight Center, Dr. R. Decher

## SPACE MASER DESIGN CONCEPT



## SCHEDULE OF PRESENT PROGRAM AND ITS EXTENSION TO A FLIGHT EXPERIMENT.



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**SENSORS AND INFORMATION SYSTEMS**

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**Sensors**

***Construction and In-Space Performance Evaluation of High-Stability Hydrogen Maser Clocks***

**Robert F.C. Vessot**

Smithsonian Astrophysical Observatory

Contract: NAS8-37752, Marshall Space Flight Center, Dr. R. Decher

**CONCLUSIONS AND SUMMARY**

**EARTH-BASED HYDROGEN MASERS HAVE ACHIEVED EXTREMELY HIGH PERFORMANCE AND STABILITY APPROACHING  $1 \times 10^{-16}$ . THIS TECHNOLOGY SHOULD BE ADAPTED FOR SPACE APPLICATIONS OF LONG DURATION.**

- **THE SPACE STATION AND POLAR ORBITER WILL REQUIRE HIGH STABILITY CLOCKS FOR**
  - **VLBI OPERATION OF SPACEBORNE RADIOTELESCOPES**
  - **WORLD WIDE TIME AND FREQUENCY COORDINATION**
  - **HIGH SPEED COMMUNICATIONS SYNCHRONIZATION**
- **HIGH PRECISION, VERY HIGH STABILITY, CLOCK SIGNALS ARE NECESSARY AS AN ON-BOARD UTILITY FOR OTHER SYSTEM APPLICATIONS.**

**MODERN METROLOGY DEPENDS ON THE DEFINITION OF TIME INTERVAL IN TERMS OF THE ATOMIC SECOND. DISTANCE IS NOW DEFINED BY THE VELOCITY OF LIGHT IN TERMS OF ATOMIC TIME.**

**ATOMIC CLOCKS PROVIDE THE MOST PRECISE MEASUREMENTS OF PHYSICAL PARAMETERS.**

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**SENSORS AND INFORMATION SYSTEMS**

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**Sensors**

***Acceleration Measurement and Management Experiment Definition***

**Jan A. Blijvoet**

University of Alabama in Huntsville (support by Teledyne Brown Engineering)

Contract: NAS1-18683, Langley Research Center, Robert C. Blanchard

General Experiment Objectives:

- Enhance the level of Acceleration Measurement and spatial patterning as an essential support to high quality microgravity operations.
- To bring acceleration measurement and management toward the mature status enjoyed by attitude and orbit determination & management.

Technology Need:

- Microgravity materials processes require:
  - \* very low acceleration disturbance levels.
  - \* knowledge of direction of the residual acceleration vector for experiment accommodation.
- No methodology available to determine on-orbit the center-of-mass.
- Acceleration disturbance level and vector needs to be known at a large number of experiment locations.
- Needs to be known in real time.
- Information needed in real time for control of the center of mass.

Experiment Definition Objectives:

- Develop analytical methods for in-orbit calculation of center of mass from a number of separately located 3-D accelerometers.
- Develop analytical methods for in-orbit calculation of acceleration level and acceleration vector at any selectable experiment location.
- Determine data for control of the center of mass.

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## SENSORS AND INFORMATION SYSTEMS

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#### *Acceleration Measurement and Management Experiment Definition*

Jan A. Blijvoet

University of Alabama in Huntsville (support by Teledyne Brown Engineering)

Contract: NAS1-18683, Langley Research Center, Robert C. Blanchard

## ACCELEROMETER MEASUREMENT AND MANAGEMENT

### SURVEY OF EXISTING ACCELEROMETERS

#### Other Similar Uses for Accelerometers

- Missile Guidance
- Satellite Sensor Stabilization
- Seismic Motion Detection
- Orbital Experiment Instrumentation

#### Teledyne Brown Engineering Requested Information from the Following Organizations:

- |                                 |                                |                           |
|---------------------------------|--------------------------------|---------------------------|
| • Applied Technology Associates | • KMS Fusion                   | • Stanford University     |
| • Bell Aerospace Textron        | • Litton                       | • Sundstrand Data Control |
| • Bruel & Kjaer                 | • Payload Systems, Inc.        | • Systron Donner          |
| • C.S. Draper Laboratories      | • Rockwell Defense Electronics | • Teledyne Geotech        |
| • G.E. Space Div.               | • Singer Kearfott              | • U of MD Physics Dept.   |
| • Honeywell                     | • Sperry Aerospace             |                           |
| • IC Sensors                    |                                |                           |

#### Specifications Requested Were:

- Measure  $10^{-7}$  to  $10^2 g_s$
- Frequency response of  $10^{-4}$  to 50 Hz
- Accommodate a noise spectrum of up to  $10^2 g_s$  from 1 to 50 Hz
- A method of calibrating the sensor

#### Conclusions:

- Currently existing sensors may be suitable for our needs, pending testing
- Sensor bias and drift characteristics will interfere with the low amplitude, low frequency measurements
- Testing and calibration will be difficult in a one  $g_s$  environment
- A new type of sensor may be more appropriate for this application

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# SENSORS AND INFORMATION SYSTEMS

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## Sensors

### Acceleration Measurement and Management Experiment Definition

Jan A. Blivest

University of Alabama in Huntsville (support by Teledyne Brown Engineering)

Contract: NAS1-18683, Langley Research Center, Robert C. Blanchard

#### POTENTIAL SHUTTLE FLIGHTS FOR PILOT EXPERIMENTATIONS

Flight, Orbiter	Date	Relevant Payload	Carrier	Low-g Flight?	Accelerometer?
32.C	Nov 89				H.O
35.C	Mar 90	Astro-1	2SL-PAL	yes?	H.O
40.C	Jun 90	SLS-1	SL-LM	?	S?, H.O
44.C	Dec 90	Atlas-1, MSL-32	2SL-PAL	yes	S?, H.O
45.A	Jan 91	TSS-1	SL-PAL, + MPSS		TBD
47.C	Apr 91	IML-1	SL-LM	yes	S, H.O
48.A	May 91	EURECA-1L		yes	TBD
49.C	Jul 91	S/L-1	SL-LM	yes	S, H.O
52.C	Dec 91	S/L-D2	SL-LM+USS	yes	H.O + TBD
55.C	Mar 92	USML-1	SL-LM+MPSS	yes	S?, H.O
56.A	Apr 92	ORPEUS	SPAS	yes	TBD
57.D	May 92	USMP-1	MSL+MPSS	yes	TBD
59.C	Jul 92	SLS-2	SL-LM	?	S?, H.O
60.A	Jul 92	ISF-1		yes	TBD
63.C	Oct 92	IML-2	SL-LM	yes	S?, H.O
65.D	Nov 92	MSL-4	MPSS	yes	S?
66.A	Feb 93	ISF-2		yes	TBD
70, OV-105	Apr 93	EURECA-2L		yes	TBD
73.C	Jul 93	USML-2	SL-LM+MPSS	yes	S?, H.O
74, OV-105	Aug 93	AAFE	2SL-PAL	?	S (Mod. 1?)
75.A	Sep 93	GP-B1	SL-PAL	yes	TBD
?	?	MSL-5	MPSS	yes	S?
?	?	MSL-6	MPSS	yes	S?

\*S = SAMS = Space Acceleration Measurement System (La R.C.)  
H = HIRAP = High Resolution Accelerometer Package  
(JSC, La R.C.)  
O = OARE = Orbital Acceleration Research Experiment  
(JSC, La R.C.)



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## SENSORS AND INFORMATION SYSTEMS

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### Sensors

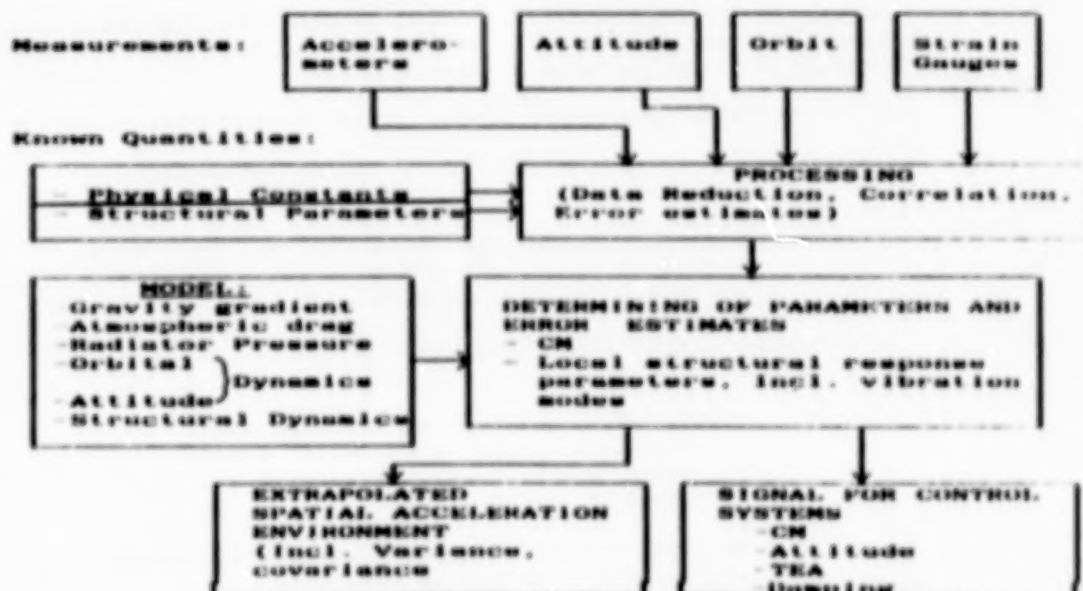
### Acceleration Measurement and Management Experiment Definition

Jan A. Blyvoet

University of Alabama in Huntsville (support by Teledyne Brown Engineering)

Contract: NAS1-18683, Langley Research Center, Robert C. Blanchard

#### M & M PROCESS FLOW



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## SENSORS AND INFORMATION SYSTEMS

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### Sensors

#### *Dynamic Spacecraft Attitude Determination with GPS*

Dr. Duncan B. Cox, Jr.

Mayflower Communications Company, Inc.

Contract: NASS-30358, Goddard Space Flight Center, Dr. Seymour Kant

#### EXPERIMENT OBJECTIVE

Determine the feasibility of using NAVSTAR GPS signals to accurately measure very small differences in antenna locations in multiple antenna arrays.

- o Determine spacecraft orbit, attitude, and flexure.

Consider shading of antennas by spacecraft structures.

Utilize optimum estimation filters, including models of spacecraft dynamics and potentially available inertial sensors.

- o Measure very slow ground motions due to geodynamics.

Utilize data obtained by continuously monitoring GPS signals at multiple sites, including stable baselines as well as potentially unstable ones.

Estimate ionospheric and tropospheric delays and multipath perturbations.

#### BACKGROUND

##### NAVSTAR Global Positioning System (GPS)

Signals soon available continuously world-wide, to LEO and beyond

Likely to be widely used for spacecraft navigation

Phase information can be used to measure lengths and bearings of short baselines with subcentimeter accuracies.

Allows determination of attitude and flexure of spacecraft with multiple antennas.

Allows determination of geodynamic motions of GPS-instrumented ground sites.

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**SENSORS AND INFORMATION SYSTEMS**

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Sc 12075

***Dynamic Spacecraft Attitude Determination with GPS***

Dr. Duncan B. Cox, Jr.

Mayflower Communications Company, Inc.

Contract: NASS-30328, Goddard Space Flight Center, Dr. Seymour Kant

**TECHNOLOGY NEEDS**

GPS-derived attitude data can be used for initial pointing of spacecraft subsystems, such as laser radars and laser communications systems. But technical issues must be resolved before mission applications are undertaken.

Spacecraft structures obscure the views of satellites and cause multipath interference.

A Geodynamic Laser Ranging System (GLRS) demonstration can benefit from having independent GPS measurements of terrestrial baselines with subcentimeter accuracies.

A system design employing low-cost, weather-tolerant, terrestrial equipment and advanced algorithms needs to be developed and demonstrated. The system should be integrated appropriately with the GLRS system.

**EXPERIMENT DESCRIPTION**

**Instrumented space vehicle**

Three GPS antennas, one GPS receiver, one high-accuracy clock, one digital controller, one data recorder.

One independent attitude determination subsystem, preferably part of a GLRS experiment. (Note that GPS receivers are likely to be utilized by GLRS for orbit determination.)

Record raw GPS pseudorange and phase data, and independent attitude data for post-flight processing. Include inertial sensor data if available.

**Instrumented terrestrial range**

A GPS antenna, receiver, and recorder at each of two GLRS sites.

Compare GPS attitude and baseline data with independent results.

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# SENSORS AND INFORMATION SYSTEMS

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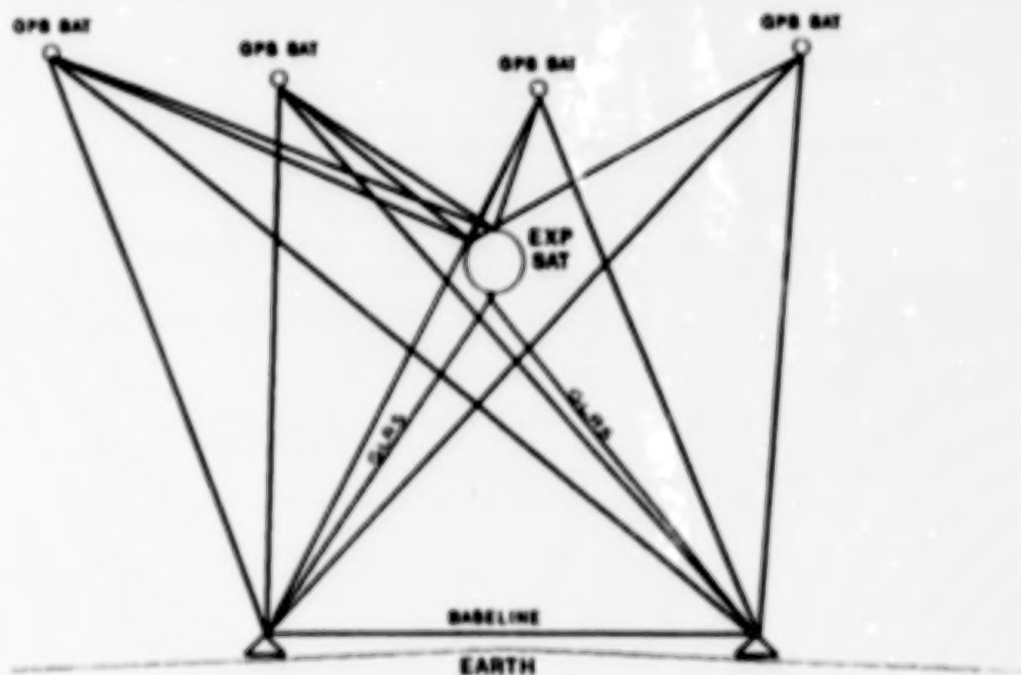
Sensors

## Dynamic Spacecraft Attitude Determination with GPS

Dr. Duncan B. Cox, Jr.

Mayflower Communications Company, Inc.

Contract: NASS-30358, Goddard Space Flight Center, Dr. Seymour Kanti



### SCHEDULE

TASK DESCRIPTION	O	N	D	J	F	M	A	M	J	J	A	S
System Description	---	---	---	---	---	---	---	---	---	---	---	---
Algorithm development				---	---	---	---	---	---	---	---	---
Hardware selection				---	---	---	---	---	---	---	---	---
Performance analysis								---	---	---	---	---
Experiment planning								---	---	---	---	---
Final report											---	---

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**SENSORS AND INFORMATION SYSTEMS**

Out-Reach

**Sensors**

***Dynamic Spacecraft Attitude Determination with GPS***

**Dr. Duncan B. Cox, Jr.**

**Mayflower Communications Company, Inc.**

**Contract: NAS5-30358, Goddard Space Flight Center, Dr. Seymour Kant**

**SUMMARY**

GPS signals probably can be used simply and at low cost to determine the attitudes of spacecraft, and bending of spacecraft members, to milliradian accuracies.

GPS signals probably can be used with low cost equipment for determination of slow geodynamic motions of terrestrial baselines to subcentimeter accuracies.

An experiment is proposed in which GPS would synergistically support a GLRM experiment.

Utilizing GLRM-spacecraft attitude data to corroborate GPS attitude data.

Utilizing GPS data to corroborate GLRM baseline data.

Using GPS data for satellite orbit estimation, to the benefit of both experiments.



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**SENSORS AND INFORMATION SYSTEMS**

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**Sensors**

***Stanford University/NASA Laser In-Space Technology Experiment (SUNLITE)***

Robert L. Byer, Stanford University  
A. Martin Buoncrisiani, Langley Research Center (National Research Council)

**OBJECTIVE:**

To provide ultra-stable, solid-state laser oscillators for future applications in space based systems. The self powered SUNLITE instrument will use the vibration free, microgravity environment in or about the orbiting Shuttle to test the stability and Schawlow-Townes linewidth limit of specially configured monolithic Non-Planar Ring Oscillators (NPRO).

**BACKGROUND:**

The availability of diode lasers, as pump sources, provides the opportunity for development of small, stable, long-life all solid-state laser sources. The monolithic Non-Planar Ring Oscillator (NPRO), developed at Stanford under NASA/OAST sponsorship, promises to satisfy scientific, medical and industrial applications requiring coherent narrow linewidth sources. Immediate benefits are promised for spacecraft operations and remote sensing applications.

Improved techniques in frequency control are used to lock the NPRO to external cavities and have yielded linewidths down to about 150 Hz. Resultant linewidth measurements are limited by noise induced by sources within the lab environment. Reducing these sources to practical limits will leave gravity, mechanical and acoustically coupled vibration as limiting factors in laboratory experiments. The Shuttle experiment will provide the environment needed to further examine linewidth and stability limitations.

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# SENSORS AND INFORMATION SYSTEMS

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Sensors

## Stanford University/NASA Laser In-Space Technology Experiment (SUNLITE)

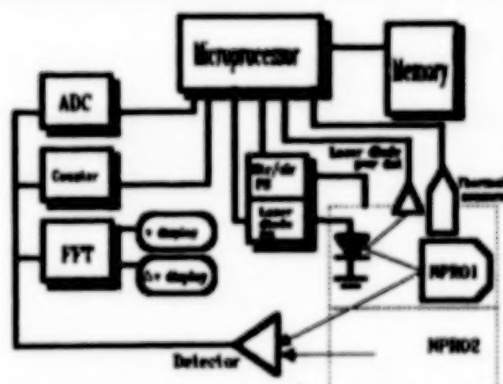
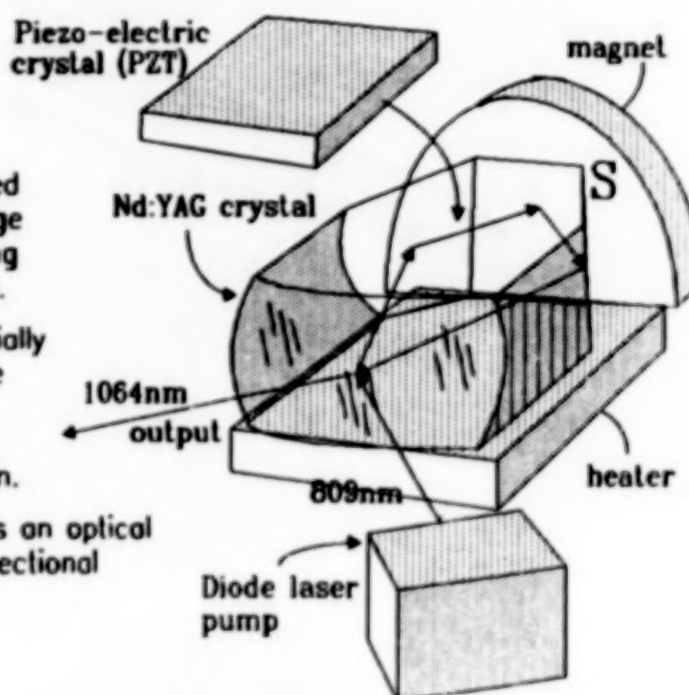
Robert L. Byer, Stanford University  
A. Martin Buoncrisiani, Langley Research Center (National Research Council)

### The NPRO Module

The Nd:YAG laser is tuned by modulating the voltage across the PZT squeezing or stretching the crystal.

The laser crystal is specially ground containing all the elements of the laser cavity taking advantage of total internal reflection.

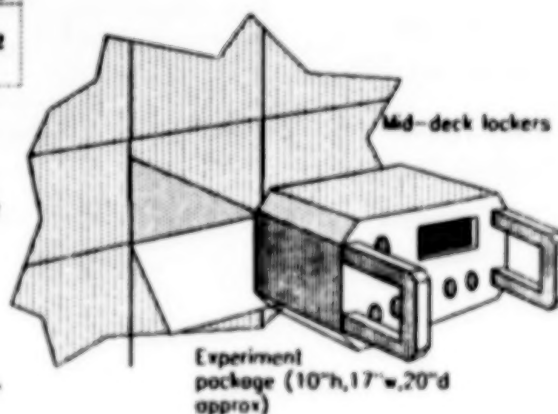
The magnet functions as an optical diode to assure a unidirectional light path.



The self contained unit will be stored in a Shuttle mid-deck locker. The experiment timeline takes about an hour, a warm-up period followed by short data taking periods. Data is stored in solid state memory for dump after the return flight.

### DESCRIPTION

The experiment consists of 3 NPROs in heterodyne pairs using photodetection for examination and recording of difference signals.



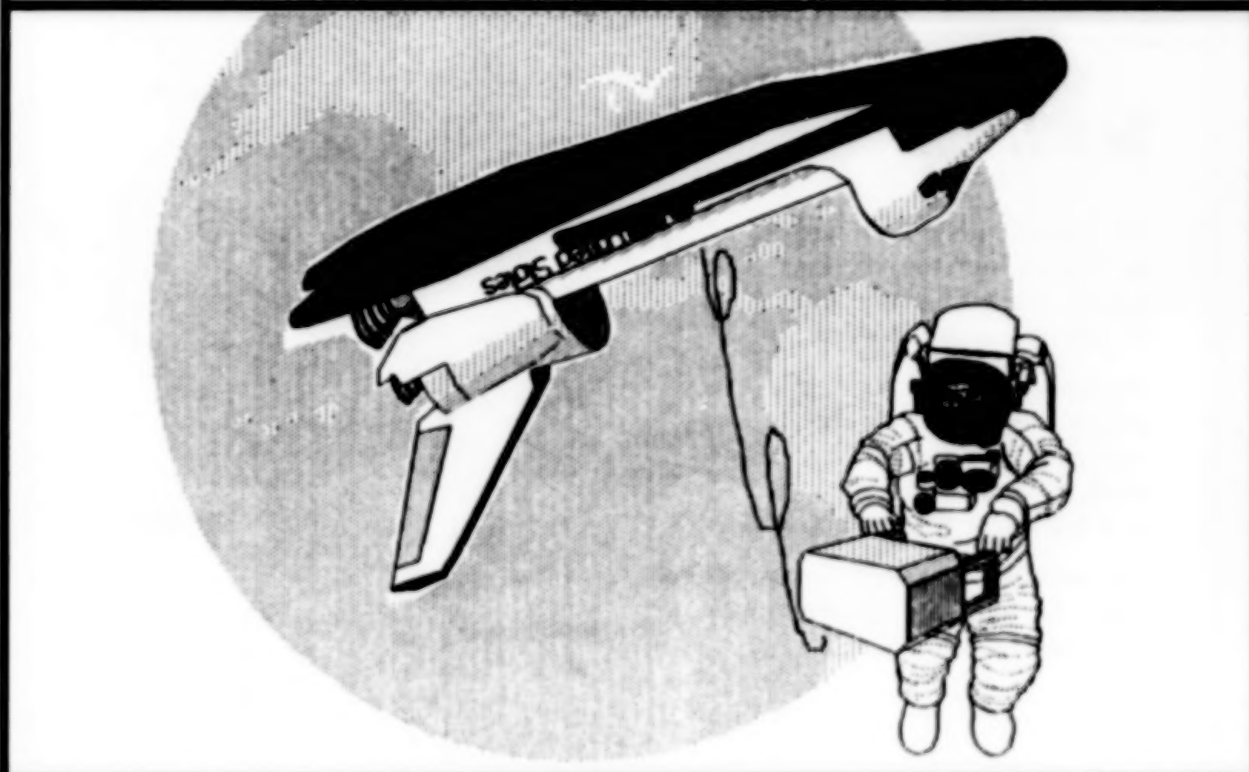
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**SENSORS AND INFORMATION SYSTEMS**  
 Sensors

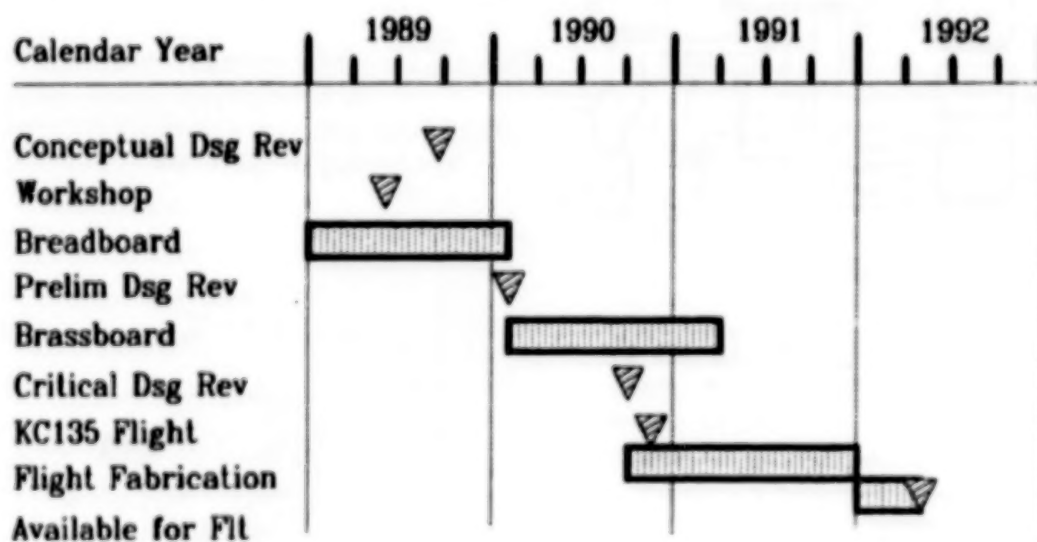
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**Stanford University/NASA Laser In-Space Technology Experiment (SUNLITE)**

Robert L. Byer, Stanford University  
 A. Martin Buoncrisiani, Langley Research Center (National Research Council)



**SCHEDULE**



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**IN-SPACE SYSTEMS**

Out-Reach

Maintenance, Repair, and Fire Safety

***Definition of Experiments to Investigate Fire Suppressants in Microgravity***

Dr. James J. Reuther

Battelle Columbus Division

Contract: NAS3-25362, Lewis Research Center, Mr. Robert Friedman

**EXPERIMENT OBJECTIVE**

- Define specific in-space technology experiment(s) to identify, evaluate, and develop effective fire suppressants for the microgravity environment. Fire suppression technology is broadly defined as the technology both to prevent ignition through atmosphere control and to extinguish smoldering and flaming combustion once initiated.

**BACKGROUND/TECHNOLOGY NEED**

- A preliminary analysis by Battelle of the combustion situation under microgravity conditions revealed that spacecraft fire suppression may be more difficult than that for 1-G fires on Earth. Specifically, fire suppressants that are routinely and rather universally used on Earth may not be as effective, or may even be ineffective, in spacecraft fire situations.
- Because there may not be proven techniques developed to extinguish fires in space, crews and hardware of future manned space missions may be at risk.



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# IN-SPACE SYSTEMS

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Maintenance, Repair, and Fire Safety

## Definition of Experiments to Investigate Fire Suppressants in Microgravity

Dr. James J. Reuther

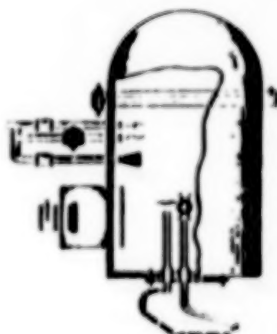
Battelle Columbus Division

Contract: NAS3-25362, Lewis Research Center, Mr. Robert Friedman

### EARLY PROGRESS

- Determination of the extent to which the effectiveness and/or mode of action of terrestrial fire suppressants are altered by the spacecraft environment.
- Formulation of guidelines with which to identify terrestrial agents that have the potential for acting as effective spacecraft fire suppressants.

### EXPERIMENT DESCRIPTION



- The apparatus will provide a means by which to simulate various flame situations representative of plausible spacecraft fire scenarios after which various means will be used to deliver and evaluate the suppression effectiveness of various agents.

### ZERO GRAVITY COMBUSTION



EARTH GRAVITY



ZERO GRAVITY

GASES



EARTH GRAVITY



ZERO GRAVITY

SOLIDS



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# IN-SPACE SYSTEMS

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Maintenance, Repair, and Fire Safety

*Definition of Experiments to Investigate Fire Suppressants in Microgravity*

Dr. James J. Reuther

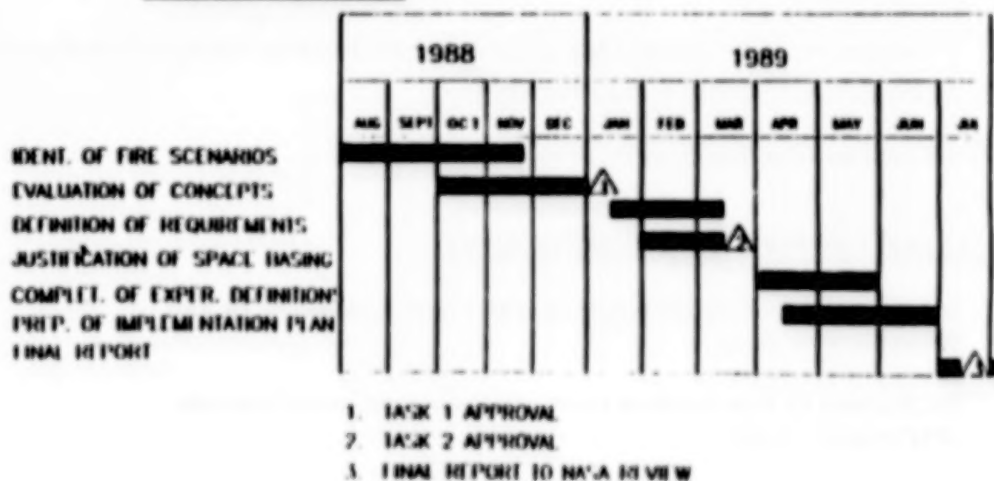
Battelle Columbus Division

Contract: NAS3-25362, Lewis Research Center, Mr. Robert Friedman

## SUMMARY/CONCLUDING REMARKS

- The mission of the project is to identify those technologies that quickly and permanently extinguish spacecraft fires, with the action taken being no more life or mission threatening than the fire itself.

## PROJECT SCHEDULE



Out-Reach

**IN-SPACE SYSTEMS**  
**Maintenance, Repair, and Fire Safety**  
***Risk-Based Fire Safety Experiment Definition***

Out-Reach

George Apostolakis  
University of California, Los Angeles  
Contract: NAS8-37750, Marshall Space Flight Center, J. Austin

**EXPERIMENT OBJECTIVE**

EXPAND THE UNDERSTANDING OF PROCESSES AND PHENOMENA IMPORTANT TO THE ASSESSMENT OF RISKS ASSOCIATED WITH FIRES IN SPACECRAFT.

- OBSERVE THE MECHANISMS OF FLAME PROPAGATION BETWEEN TWO SOLID OBJECTS AND THE COMPETING PROCESSES OF DETECTION AND SUPPRESSION.
- OBSERVE THE GENERATION, MOTION, AND ADVERSE IMPACT OF COMBUSTION PRODUCTS.
- CONTRIBUTE TO THE DEVELOPMENT OF PROBABILISTIC RISK ASSESSMENT METHODOLOGY FOR SPACECRAFT.

**BACKGROUND**

- QUANTITATIVE RISK ASSESSMENT IS PLAYING AN INCREASINGLY IMPORTANT ROLE IN IDENTIFYING SIGNIFICANT RISKS AND JUSTIFYING MITIGATING ACTIONS (SEE ALSO NMI 8070.4)
- PRA METHODOLOGY QUANTIFYING THE FIRE RISK IN NUCLEAR POWER PLANTS HAS BEEN DEVELOPED AT UCLA.

**TECHNOLOGY NEEDS**

- TO INTEGRATE BASIC KNOWLEDGE ACQUIRED IN PREVIOUS MICROGRAVITY RESEARCH TO INVESTIGATE SYSTEM LEVEL PHENOMENA
- TO EXPAND BASIC FIRE-SAFETY KNOWLEDGE

**OUTLINE OF FIRE RISK ASSESSMENT**

1. IDENTIFICATION OF "CRITICAL" LOCATIONS AND ASSESSMENT OF THE FREQUENCY OF FIRES.
2. ESTIMATION OF FIRE GROWTH TIMES AND COMPETING DETECTION AND SUPPRESSION TIMES.

$$Q = Fr\{T_G < T_D + T_S | FIRE\}$$

3. RESPONSE OF THE SYSTEM.

$$1 + 2 + 3 \Rightarrow \lambda_D = \sum \lambda_j Q_{D|j} Q_{D|D,j}$$

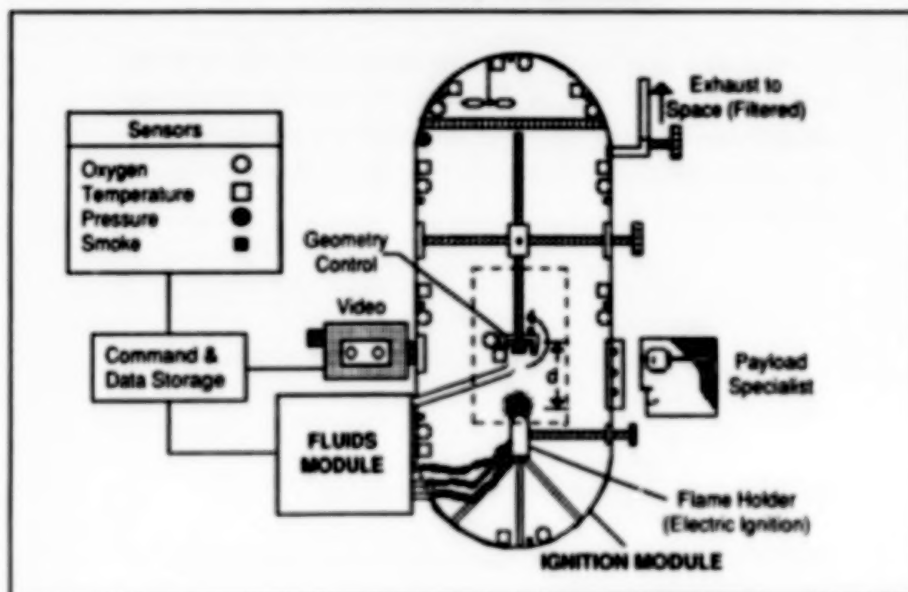
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**IN-SPACE SYSTEMS**  
Maintenance, Repair, and Fire Safety  
**Risk-Based Fire Safety Experiment Definition**

Out-Reach

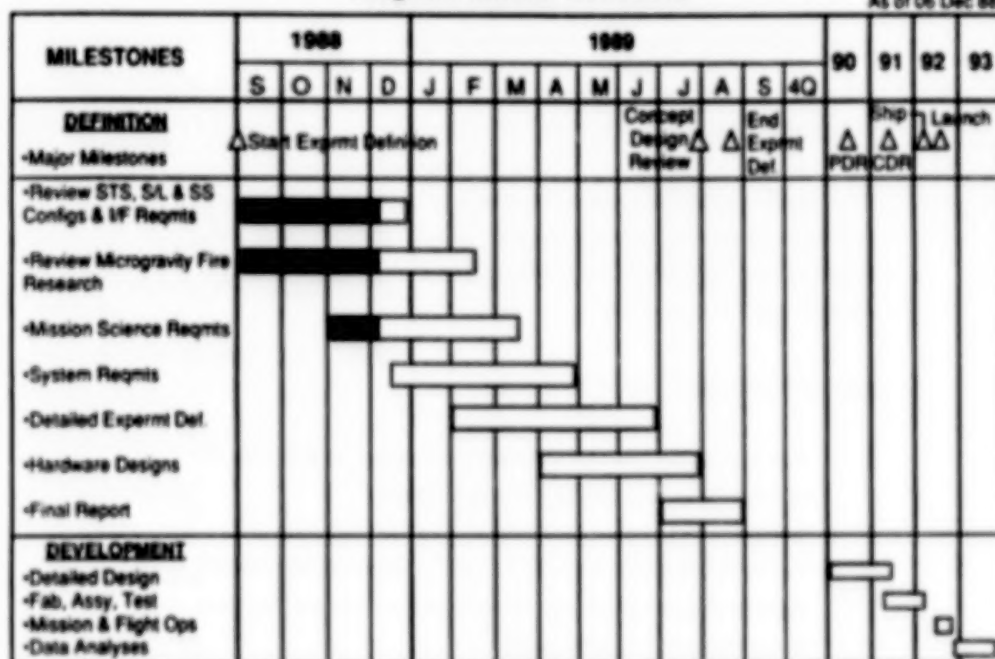
George Apostolakis  
University of California, Los Angeles  
Contract: NAS8-37750, Marshall Space Flight Center, J. Austin

**Preliminary Schematic**



**Program Master Schedule**

As of 06 Dec 88



Out-Reach

**IN-SPACE SYSTEMS**  
**Materials Processing**  
**Plasma Arc Welding In Space**

Out-Reach

**Boris Rubinsky**  
University of California, Berkeley  
Contract: NAS1-18686, Langley Research Center, Dr. John Buckley

**EXPERIMENT OBJECTIVE**

TO DEVELOP A FUNDAMENTAL UNDERSTANDING OF THE HEAT TRANSFER, MASS TRANSFER AND FLUID FLOW PROCESSES THAT OCCUR DURING PLASMA ARC WELDING IN A LOW-GRAVITY AND LOW PRESSURE ENVIRONMENT. TO DEVELOP CORRELATIONS WITH ANALYTICAL MODELS. THIS UNDERSTANDING WILL BE APPLIED TO:

- THE IDENTIFICATION OF THE OPTIMAL PARAMETERS FOR PLASMA ARC WELDING IN SPACE.
- THE DESIGN OF LOW WEIGHT TASK SPECIFIC PLASMA ARC WELDING SYSTEMS.

**BACKGROUND/TECHNOLOGY NEEDS**

- COMPUTER MODEL OF THE PLASMA ARC WELDING PROCESS FOR THE IDENTIFICATION OF WELDING PARAMETERS.
- ANALYTICAL AND EXPERIMENTAL METHOD FOR THE ANALYSIS OF THE EXPERIMENTAL DATA RETRIEVED FROM THE IN-SPACE EXPERIMENT.
- EXPERIMENTAL SYSTEMS FOR VERIFICATION OF THE ABOVE METHODS IN GROUND-BASED LABORATORIES.

**COMPUTER MODEL**

A FINITE ELEMENT COMPUTER MODEL WILL PROVIDE THE ABILITY TO DETERMINE THE SHAPE OF THE LIQUID REGION AND THE TEMPERATURE DISTRIBUTION IN THE SOLID REGION AS A FUNCTION OF GRAVITY AND AIR PRESSURE.

ASSUMPTIONS USED IN THE STUDY INCLUDE:

- THE PROCESS IS QUASI-STATIONARY AS VIEWED IN A FRAME OF REFERENCE MOVING WITH THE PLASMA TORCH.
- THE MOLTEN LIQUID IS NEWTONIAN AND INCOMPRESSIBLE.
- THE HEAT TRANSFER AND FLUID FLOW CORRELATIONS FOR THE FLOW OF PLASMA ARE TAKEN FROM KNOWN EXPERIMENTAL DATA FOR FLOW OF PLASMAS IN TUBES.
- MATERIAL PROPERTIES ARE TEMPERATURE DEPENDENT.

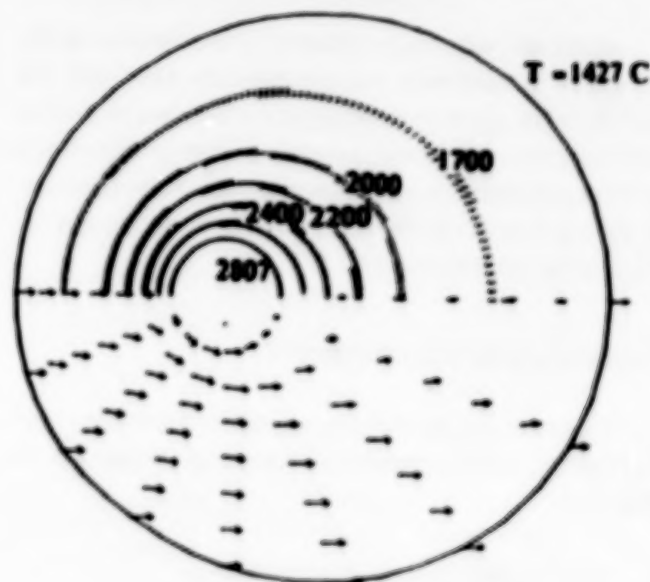
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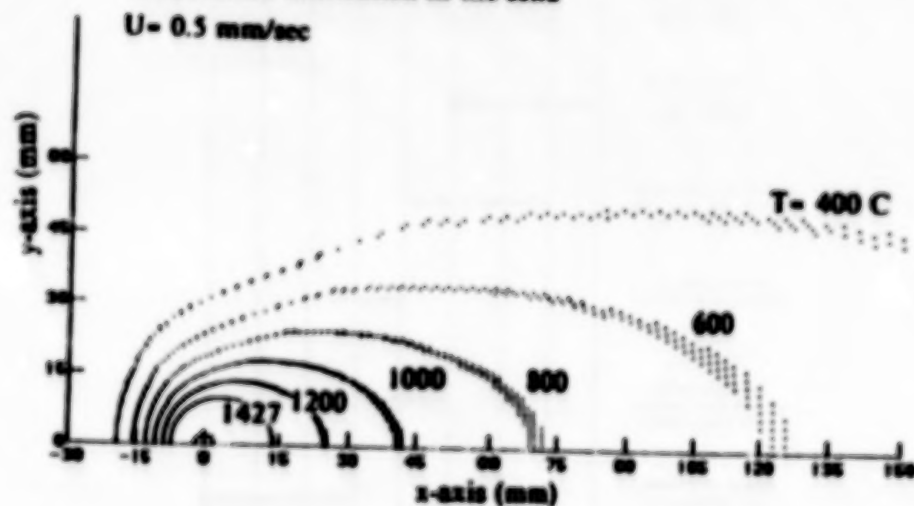
**IN-SPACE SYSTEMS**  
**Materials Processing**  
**Plasma Arc Welding in Space**

Boris Rubinsky  
 University of California, Berkeley  
 Contract: NAS1-18686, Langley Research Center, Dr. John Buckley

Velocity and temperature distributions  
 in the molten pool,  $U = 0.5$  mm/sec



Temperature distribution in the solid  
 $U = 0.5$  mm/sec





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**IN-SPACE SYSTEMS**  
**Materials Processing**  
**Plasma Arc Welding in Space**  
**Boris Rubinsky**  
University of California, Berkeley  
Contract: NAS1-18686, Langley Research Center, Dr. John Buckley

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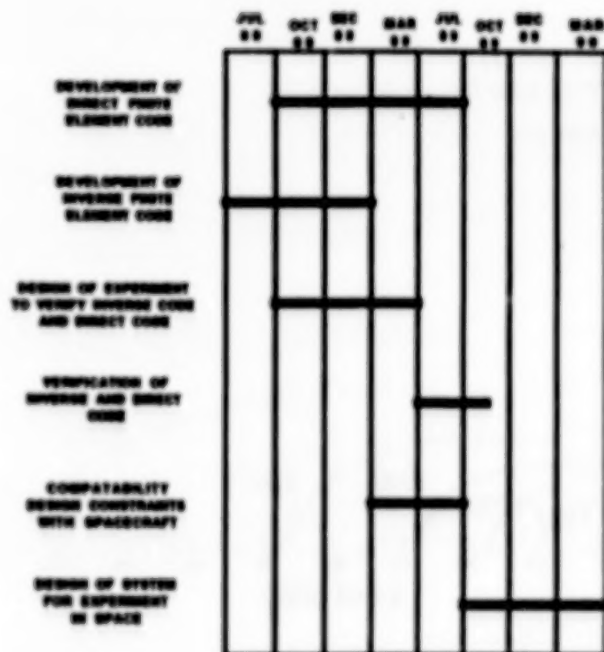
# **ANALYTICAL/EXPERIMENTAL METHOD FOR DATA ANALYSIS**

AN INVERSE FINITE ELEMENT COMPUTER PROGRAM WILL PROVIDE THE ABILITY TO DETERMINE THE TEMPERATURE FIELD AND THE POSITION OF THE SOLID-LIQUID INTERFACE DURING WELDING USING CONTINUOUS TEMPERATURE AND HEAT FLUX MEASUREMENTS TAKEN ON THE OUTER SURFACE OF THE WORKPIECE, AWAY FROM THE WELD REGION. THE METHOD COULD ALSO PROVIDE REAL TIME CONTROL OVER THE QUALITY OF THE WELDING PROCESS.

## **ON GROUND LABORATORY EXPERIMENTS**

THE DIRECT AND INVERSE FINITE ELEMENT COMPUTER CODES WILL BE VERIFIED USING A COMMERCIAL PLASMA ARC WELDING SYSTEM THROUGH:

- THERMOCOUPLE TEMPERATURE MEASUREMENTS.
- HIGH POWER FLASH X-RAY PHOTOGRAPHY.
- METALLURGICAL CROSS SECTIONS.



Out-Reach

**IN-SPACE SYSTEMS**

Out-Reach

Materials Processing

**Extra-Vehicular Activity Welding Experiment**

Gary Schnittgrund

Rockwell International Corporation, Rocketdyne Division

Contract: NAS8-37753, Marshall Space Flight Center, Arthur C. Nunes

**Experiment Objective**

Generate data to assess flight crew capability to perform on-orbit EVA welding operations

- Investigate equipment requirements
- Investigate crew/equipment & crew/process interaction
- Investigate weld automation
- Evaluate process/material compatibility
- Define critical human factors

**Background**

- Soviets welding in space since 1965
- Welding in vacuum demonstrated by Rocketdyne
- "Enabling" for Pathfinder missions

**Technology Needed**

- Welding is a versatile joining technique for diverse materials
- Welding applicable to contingency repair or in-space construction

**Need for space experiment**

- Extended duration of space flight gives environment integrated weld data
- Welding process sensitive to human factors

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IN-SPACE SYSTEMS

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Materials Processing

**Extra-Vehicular Activity Welding Experiment**

Gary Schnittgrund

Rockwell International Corporation, Rocketdyne Division

Contract: NAS8-37753, Marshall Space Flight Center, Arthur C. Nunes

**Russian Astronaut Welding  
in Space (1986)**



**Experiment Description**

**Issues**

- Equipment requirements
- Process interactions
- Materials effects
- Human factors

**On-Orbit Tasks**

- Manual GTA welding
- Semiautomatic in-place GTA tube welding
- Various materials, configurations, orientations, parameters

**Baseline Data**

- KC-135 low-G tube welding
- Gas can (G-169) tube welding experiment
- Pressure-suited manual welding tests
- KC-135 manual welding tests
- Laboratory process development

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**IN-SPACE SYSTEMS**

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Materials Processing

***Extra-Vehicular Activity Welding Experiment***

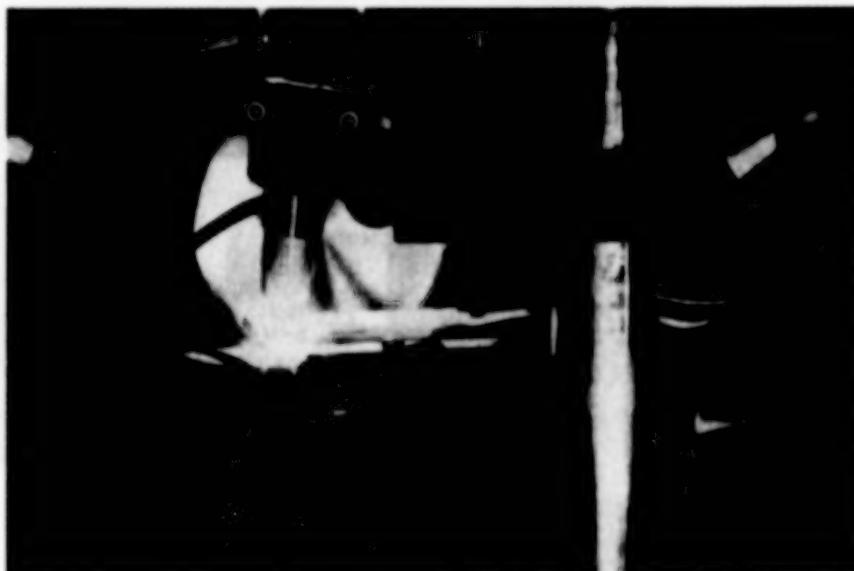
Gary Schnittgrund

Rockwell International Corporation, Rocketdyne Division  
Contract: NAS8-37753, Marshall Space Flight Center, Arthur C. Nunes

**Tungsten Inert Gas (TIG) Vacuum Welding Apparatus**



**Tungsten Inert Gas Vacuum Welding Experiment**



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IN-SPACE SYSTEMS

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Materials Processing

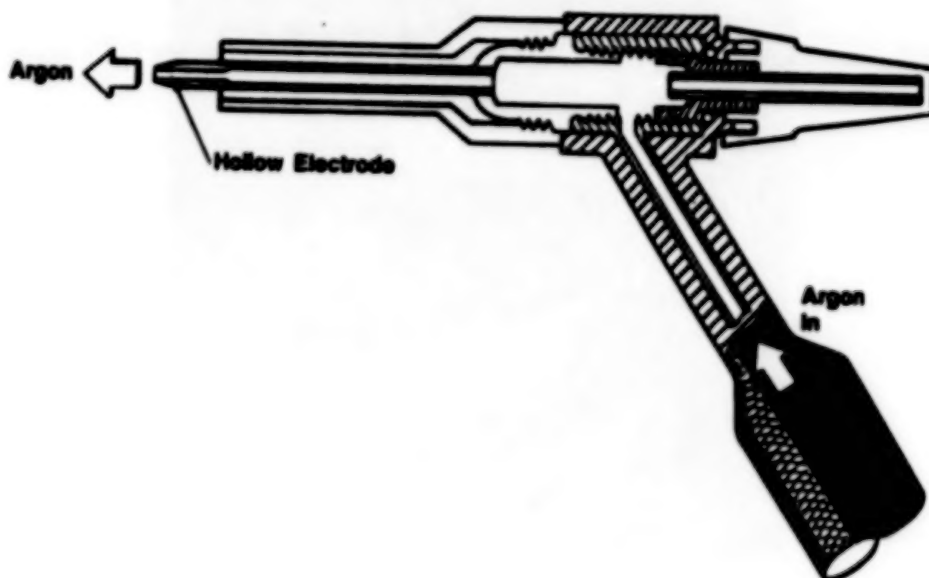
**Extra-Vehicular Activity Welding Experiment**

Gary Schnittgrund

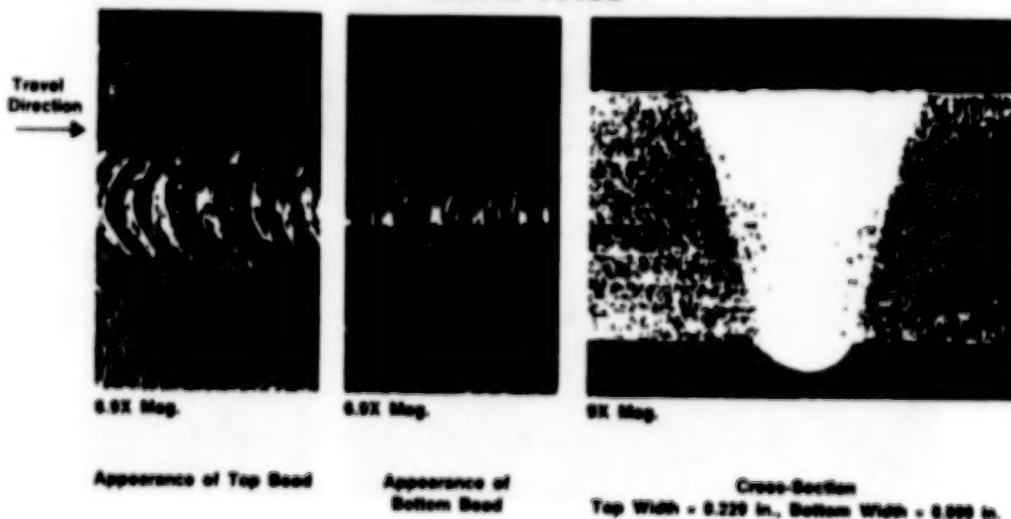
Rockwell International Corporation, Rocketdyne Division

Contract: NAS8-37753, Marshall Space Flight Center, Arthur C. Nunes

**Rocketdyne Vacuum GTAW Torch**



**Automatically Pulsed Single Pass  
Full Penetration Vacuum GTA Weld  
Material 304SS**





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**IN-SPACE SYSTEMS**  
**Materials Processing**

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***Extra-Vehicular Activity Welding Experiment***

Gary Schnittgrund

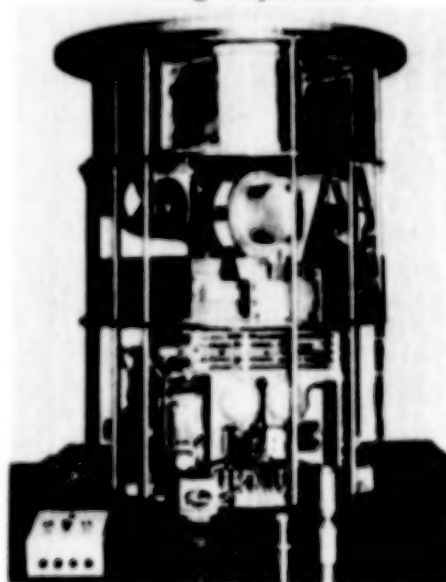
Rockwell International Corporation, Rocketdyne Division

Contract: NAS8-37753, Marshall Space Flight Center, Arthur C. Nunes

**KC-135 Welding Flight Experiments**



**Rockwell International/Cal Poly Gas Can  
Welding Experiment**



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**IN-SPACE SYSTEMS**

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**Materials Processing**

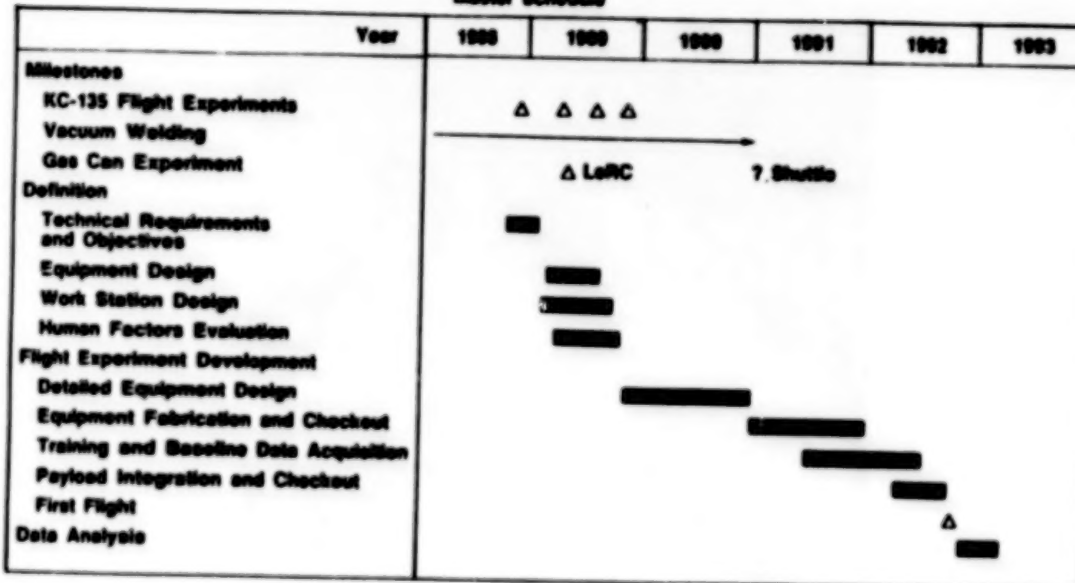
***Extra-Vehicular Activity Welding Experiment***

Gary Schnittgrund

Rockwell International Corporation, Rocketdyne Division

Contract: NAS8-37753, Marshall Space Flight Center, Arthur C. Nunes

Master Schedule



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**IN-SPACE SYSTEMS**

Out-Reach

**Materials Processing**

***On-Orbit Electron Beam Welding Experiment***

**William Hooper**

**Martin Marietta Aerospace, Manned Space Systems**

**Contract: NAS8-37756, Marshall Space Flight Center, Arthur C. Nunes**

**EXPERIMENT OBJECTIVE**

**DESIGN AN EXPERIMENT THAT WILL DEMONSTRATE THAT THE ELECTRON BEAM PROCESS CAN SAFELY PRODUCE HIGH INTEGRITY WELDS IN THE SPACE ENVIRONMENT.**

**SPECIFICALLY ADDRESS THE EXPERIMENT DESIGN TO THE REPAIR OF MICROMETEOROID STRIKE DAMAGE TO STRUCTURAL PANELS AND THE TYPE OF ALLOY SPECIFIED FOR THE SPACE STATION STRUCTURES.**

**PROVIDE FOR CORRELATION BETWEEN SPACE-DERIVED AND GROUND-BASED DATA**

**BACKGROUND**

**PRIOR WORK**

- **D-56R: ONORBIT WELDING AND CUTTING**
- **M-42R: LONG TERM SPACE EXPOSURE OF METALS**
- **M-01S: SPACE DEBRIS AND METEOROID PROTECTION**
- **M-05S: MANNED SPACECRAFT EVA REPAIR**

**DEMONSTRATES**

- **LONG TERM RISK OF PENETRATION DAMAGE**
- **TYPE OF DAMAGE**
- **COMPATIBILITY OF EB WELDING PROCESS WITH EVA REPAIR**

**TECHNOLOGY NEED**

- **CANNOT PREDICT EB WELD BEAD PUSH-THROUGH CAPACITY IN ABSENCE OF GRAVITY EFFECTS**
- **SOLIDIFICATION CHARACTERISTICS OF WELD BEAD METAL IN MICROGRAVITY AND EFFECT ON WELD PROPERTIES**

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**IN-SPACE SYSTEMS**  
**Materials Processing**

Out-Reach

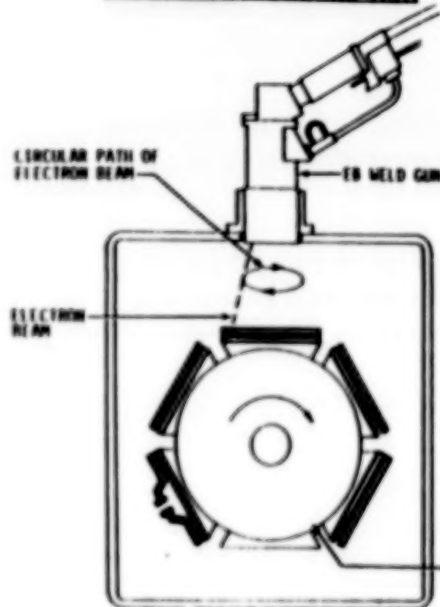
***On-Orbit Electron Beam Welding Experiment***

William Hooper

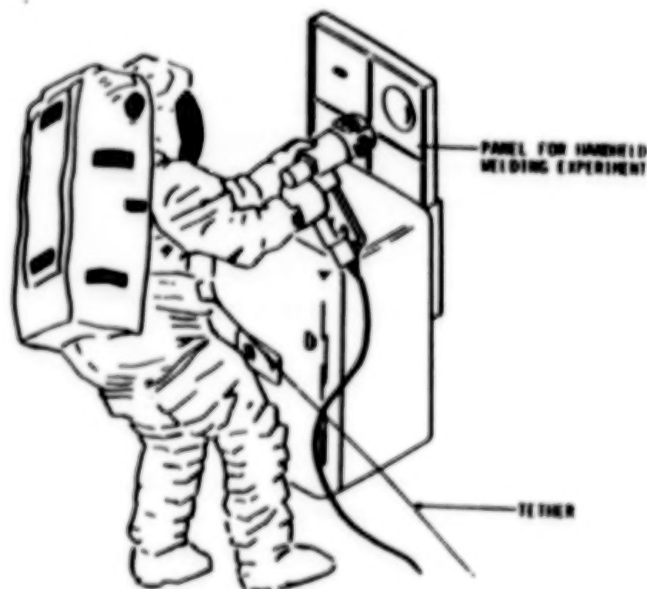
Martin Marietta Aerospace, Manned Space Systems

Contract: NAS8-37756, Marshall Space Flight Center, Arthur C. Nunes

**EXPERIMENT DESCRIPTION**

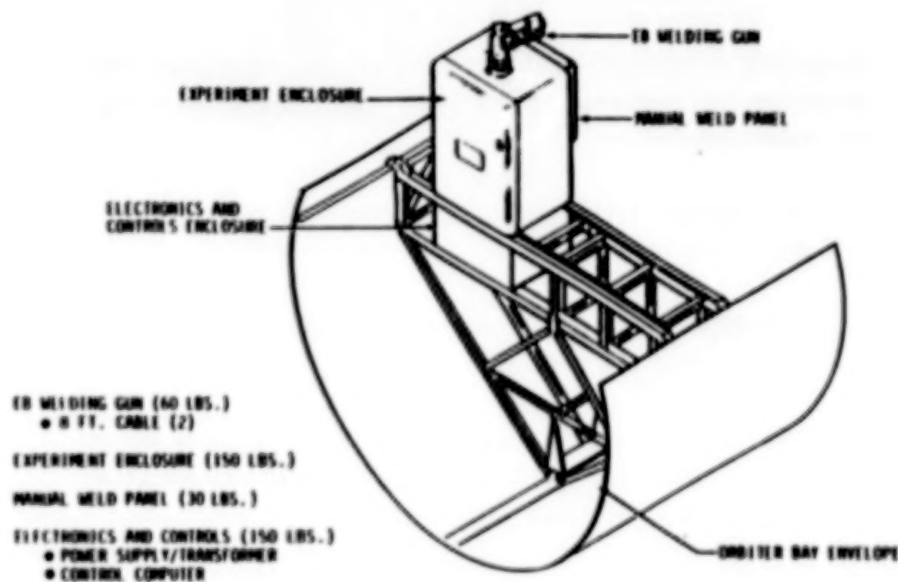


- SIX WELD PANEL CONFIGURATIONS AND WELD SCHEDULES ARE DEVELOPED
- ONE SET OF SIX PANELS IS WELDED IN GROUND-BASED EXPERIMENT
- AN IDENTICAL SET IS MOUNTED FOR ONORBIT EXPERIMENT
- ONORBIT ENCLOSURE IS PORTED TO SPACE: THE AUTOMATED CYCLE OF WELDS IS REPEATED
- THE OPTIONAL HAND-HELD WELDING EXPERIMENT IS COMPLETED
- PROPERTIES OF ONORBIT WELDED AND GROUND-LEVEL WELDED PANELS ARE COMPARED



### Out-Reach

**On-Orbit Electron Beam Welding Experiment**  
William Hooper  
Martin Marietta Aerospace, Manned Space Systems  
Contract: NAS8-37756, Marshall Space Flight Center, Arthur C. Nunes



### CONCEPTUAL DESIGN STUDY TASKS

- 1) DEVELOP OBJECTIVES FOR A SPECIFIC EXPERIMENT
- 2) DEFINE EXPERIMENT REQUIREMENTS
- 3) VERIFY EXPERIMENT REQMTS COMPATIBLE WORKER
- 4) PERFORM EXPERIMENT DESIGN
- 5) EQUIPMENT TRADE STUDIES-SELECT OPTION
- 6) INTEGRATE EXPERIMENT & EQUIPMENT SELECTION

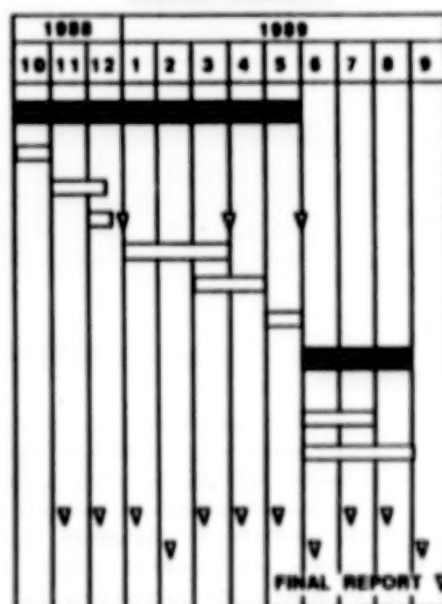
## EXPERIMENT IMPLEMENTATION PLAN

### STUDY TASKS

- 8) IMPLEMENTATION PLAN & COSTS

### CONCEPTUAL DESIGN STUDY TASKS

- MONTHLY REPORTS
- PROGRESS REVIEWS





<b>INSTEP88 Workshop</b> <b>OAST Technology For the Future</b> <b>Part 1: Executive Summary &amp; Experiment Descriptions</b>	<b>Experiment Descriptions</b>
<b>Out-Reach</b>	<div data-bbox="724 277 992 315"><b>IN-SPACE SYSTEMS</b></div> <div data-bbox="735 315 981 353"><b>Materials Processing</b></div> <div data-bbox="724 353 992 392"><b>Laser Welding in Space</b></div> <div data-bbox="635 392 1085 430"><b>Dr. Gary L. Wortman and Dr. William F. Kauder</b></div> <div data-bbox="690 430 1029 468"><b>University of Alabama in Huntsville</b></div> <div data-bbox="561 468 1155 501"><b>Contract: NAS9-17962, Johnson Space Center, Jay Bennett</b></div> <div data-bbox="1328 277 1451 315"><b>Out-Reach</b></div>
<div data-bbox="668 539 1055 577"><b>EXPERIMENT OBJECTIVES</b></div> <p data-bbox="455 645 1249 757">To develop a conceptual understanding of the significant characteristics of laser welding for space applications, including the following:</p> <ul data-bbox="510 792 1202 981" style="list-style-type: none"> <li>Operational characteristics of a laser welder in a micro gravity environment.</li> <li>Correlations between ground-based welds and those performed in low-gravity.</li> </ul> <p data-bbox="455 1016 1249 1128">This understanding will be used to develop an optimal design for a space based laser welding facility which can be used for assembly or repair of space structures.</p> <div data-bbox="618 1182 1149 1220"><b>BACKGROUND/TECHNOLOGY NEEDS</b></div> <p data-bbox="455 1263 769 1301"><b>Need for In-flight Experiment</b></p> <ul data-bbox="510 1301 1290 1473" style="list-style-type: none"> <li>To develop experience in welding operations in Space where processes and materials can behave differently</li> <li>To evaluate suitability of laser power and beam delivery systems for Space Systems operation.</li> <li>To determine overall man-process interactions and required level of automation for operations aboard a space structure.</li> </ul> <p data-bbox="455 1496 813 1534"><b>Essential Technology Advancements</b></p> <ul data-bbox="510 1534 1155 1646" style="list-style-type: none"> <li>High efficiency solid-state lasers.</li> <li>Alternate sources of pumping. (solar)</li> <li>Robotized fiber-optic beam coupling system.</li> <li>Demonstrations of materials joining capability other than metals.</li> </ul> <div data-bbox="678 1697 1081 1736"><b>EXPERIMENT DESCRIPTION</b></div> <p data-bbox="455 1778 1290 1980">The space based laser welding facility will be used to weld tubular components using a solid-state laser with a fiber-optic beam delivery system. Variable weld parameters will include weld material, laser energy, and weld speed. Temperature measurements adjacent to the weld seam will be used correlate processing parameters of each sample. Ground based metallurgical and weld strength analysis will be used to determine consistency in the overall weld process and the reliability of the space based welds.</p>	

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**IN-SPACE SYSTEMS**  
**Materials Processing**  
**Laser Welding in Space**

Out-Reach

Dr. Gary L. Workman and Dr. William F. Kaulder  
 University of Alabama in Huntsville  
 Contract: NAS9-17962, Johnson Space Center, Jay Bennett

Current version of  
 the KC-135 laser  
 welding experimental  
 apparatus.



Sample chamber  
 under vacuum



Laser welding experiments as  
 performed here on the NASA KC-135  
 are used to obtain information about  
 weld solidification and heat transfer  
 in a microgravity environment.



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# IN-SPACE SYSTEMS

Out-Reach

## Materials Processing

### Laser Welding in Space

Dr. Gary L. Workman and Dr. William F. Kauder

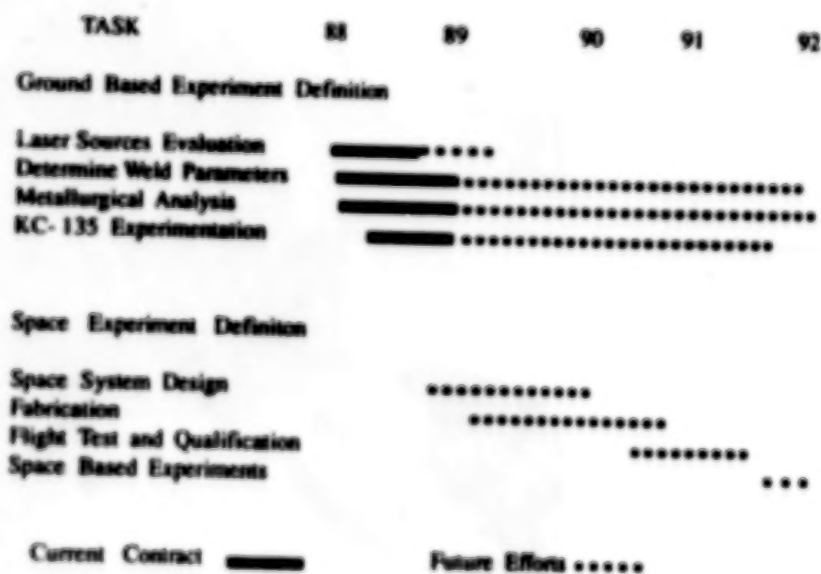
University of Alabama in Huntsville

Contract: NAS9-17982, Johnson Space Center, Jay Bennett

## SUMMARY

Laser welding experiments have been performed on the KC-135 aircraft resulting in a preliminary definition for a space based welding facility using a solid-state laser with fiber-optic delivery system and solar pumping for an alternate source of energy.

## SCHEDULE



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**IN-SPACE SYSTEMS**  
**Materials Processing**

Out-Reach

***Liquid Encapsulated Float Zone Refining of Gallium Arsenide***

**Edward Barocals**

**McDonnell Douglas Astronautics Company**

**Contract: NAS3-25380, Lewis Research Center, Amos Chait**

**EXPERIMENT OBJECTIVE**

**DEMONSTRATE THE FEASIBILITY OF A NEW FLOAT ZONE REFINING PROCESS THAT TAKES ADVANTAGE OF MICROGRAVITY TO PRODUCE DEFECT-FREE SEMICONDUCTORS.**

- INVESTIGATE THE BENEFITS OF CONTAINERLESS PROCESSING ON GALLIUM ARSENIDE CRYSTAL QUALITY.
- DEMONSTRATE THE FEASIBILITY OF USING A FREE SURFACE ENCAPSULANT IN MICROGRAVITY.
- TEST THE STABILITY OF AN ENCAPSULATED GALLIUM ARSENIDE FLOATING ZONE.

**BACKGROUND**

**COMPOUND SEMICONDUCTORS PLAY AN INCREASINGLY IMPORTANT ROLE IN AEROSPACE TECHNOLOGY.**

- HIGH SPEED COMPUTERS      • RADIATION HARDENED ELECTRONICS
- SOLID STATE LASERS        • OPTICAL DETECTORS

**TECHNOLOGY NEED**

- GROWING CRYSTALS OF COMPOUND SEMICONDUCTORS IS DIFFICULT IN THE PRESENCE OF GRAVITATIONAL EFFECTS.
- CONTAINER WALLS INTRODUCE CRYSTAL STRAIN AND CHEMICAL CONTAMINANTS.
- HIGH DENSITY IC'S REQUIRE LOW DOPANT CONCENTRATIONS: LIQUID ENCAPSULATION PREVENTS CONTAMINATION FROM FURNACE COMPONENTS.

**NEED FOR SPACE EXPERIMENT**

- GALLIUM ARSENIDE CANNOT BE FLOAT ZONE PROCESSED IN GRAVITY.
- FREE SURFACE ENCAPSULANT WOULD FLOW IN GRAVITY.

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# IN-SPACE SYSTEMS

Out-Reach

## Materials Processing

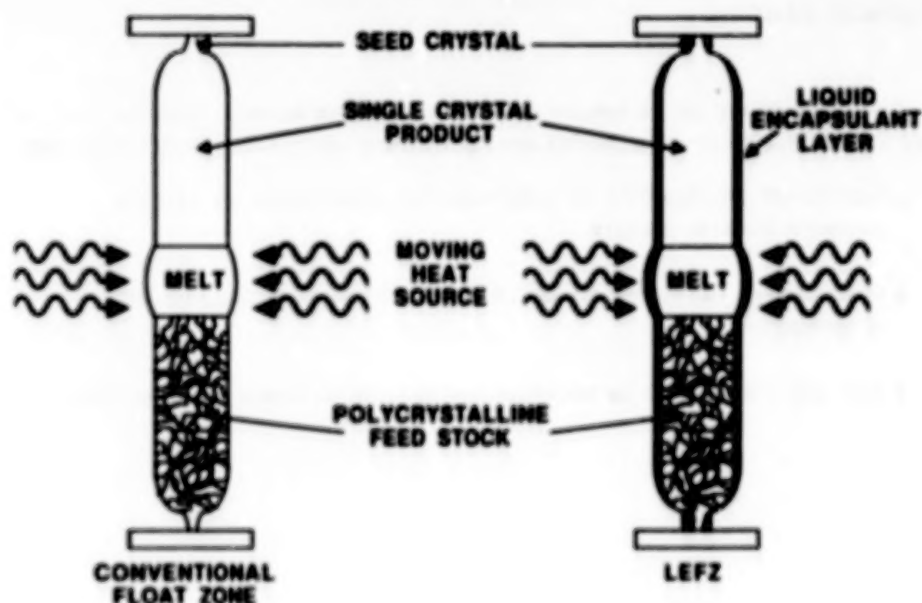
### Liquid Encapsulated Float Zone Refining of Gallium Arsenide

Edward Barocela

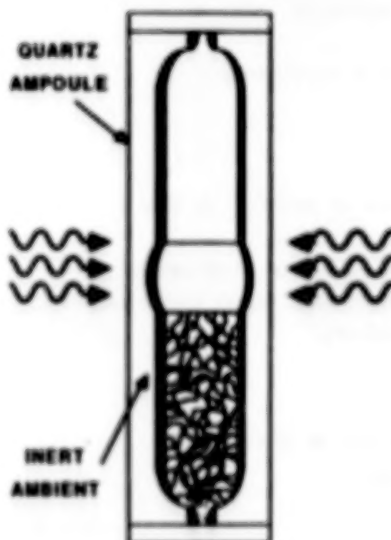
McDonnell Douglas Astronautics Company

Contract: NAS3-25380, Lewis Research Center, Amos Chait

#### PROCESS DESCRIPTION



#### EXPERIMENT DESCRIPTION



- A ROD OF GALLIUM ARSENIDE IS COATED WITH A THIN LAYER OF BORON TRIOXIDE ENCAPSULANT.
- THE SAMPLE ROD IS SEALED INTO A QUARTZ AMPOULE, WHICH IS FILLED WITH DRY NITROGEN OR ARGON.
- THE SAMPLE IS FLOAT ZONE PROCESSED IN MICROGRAVITY.
- THERMAL AND OPTICAL OBSERVATIONS ARE MADE ON ORBIT TO DOCUMENT THE PROCESS. THESE OBSERVATIONS WILL BE ANALYZED TO ASSESS THE BEHAVIOR OF THE COMBINED LIQUID ENCAPSULANT-MOLTEN SEMICONDUCTOR SYSTEM AND THE SOLID-LIQUID INTERFACE.
- THE SAMPLE WILL BE COMPARED ON THE GROUND WITH TERRESTRIALLY GROWN MATERIAL.



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IN-SPACE SYSTEMS

Out-Reach

Materials Processing

*Liquid Encapsulated Float Zone Refining of Gallium Arsenide*

Edward Barocals

McDonnell Douglas Astronautics Company

Contract: NAS3-25380, Lewis Research Center, Amos Chait

THERMAL MODELING - NEAR TERM TASKS

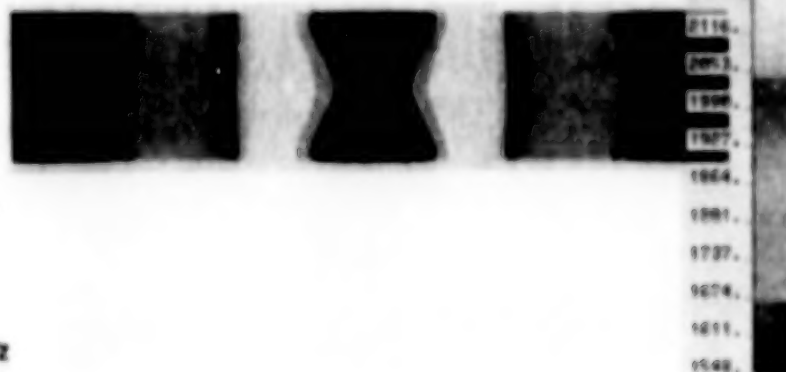
• REFINE BASELINE OPERATING PARAMETERS TO OPTIMIZE:

- ELECTRICAL POWER CONSUMPTION
- PEAK TEMPERATURE
- THERMAL GRADIENTS

• ESTABLISH REQUIREMENTS FOR COATING PROCESS BY INVESTIGATING THE EFFECTS OF:

- DIFFERENT ENCAPSULANT THICKNESSES
- ENCAPSULANT THICKNESS NONUNIFORMITIES
- PINHOLES IN THE ENCAPSULANT

GALLIUM ARSENIDE CRYSTAL GROWTH  
 1.07 MM BORON TRIOXIDE COATING  
 HEAT FLUX = 25 W/CM<sup>2</sup>  
 TIME = 1800 SEC.  
 EMISSIVITY = 100%  
 HEATER BEGINS TO MOVE AT T = 298.63 SEC



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**IN-SPACE SYSTEMS**  
**Materials Processing**

Out-Reach

*Liquid Encapsulated Float Zone Refining of Gallium Arsenide*

Edward Barocals

McDonnell Douglas Astronautics Company

Contract: NAS-35530, Lewis Research Center, Amos Chait

**MASTER SCHEDULE**

YEAR QTR	1988				1989				1990				1991				1992			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
TECHNICAL REQUIREMENTS AND OBJECTIVES																				
HARDWARE CONCEPT																				
PROJECT PLAN																				
SYSTEM DESIGN																				
FABRICATION AND ASSEMBLY																				
TEST AND FLIGHT QUALIFICATION																				
PAYLOAD INTEGRATION AND CHECK OUT																				
FIRST FLIGHT																				

Out-Reach

**IN-SPACE SYSTEMS**  
**Materials Processing**

Out-Reach

**Vapor Crystal Growth Technology**

**Franz E. Rosenberger and Francis C. Weasling**

University of Alabama Center for Microgravity and Materials Research (support by Boeing)

Contract: NAS3-25361, Lewis Research Center, Walter Duval

**EXPERIMENT OBJECTIVE**

Develop a novel vapor growth technology that results in increased flexibility in the control of the process parameters for high quality crystal growth in space and on earth.

Emphasis on:

- Advantageous crystal nucleation and growth location
- Growth of a controlled number (preferably one) of single crystals
- Reduced mechanical interaction between ampoule and crystal, in particular during cooldown
  - higher structural quality
- Continuous removal of volatile impurities
  - higher purity
- Increased growth rates

**BACKGROUND/TECHNOLOGY NEED**

NASA and ESA-sponsored researchers, and workers in the USSR have been conducting vapor growth experiments in space.

Crystal growth from vapors has many advantages over other techniques.

All low gravity vapor growth experiments have been carried out in closed ampoules and traditional heating geometries, thus resulting in

- little control of number of size of crystals grown,
- relatively low growth rates
  - particularly important in view of limited experiment time in space

Despite these shortcomings, vapor growth in space has yielded very promising results.

**To take full advantage of microgravity conditions  
for vapor crystal growth a novel technology is needed.**

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**IN-SPACE SYSTEMS**  
**Materials Processing**

Out-Reach

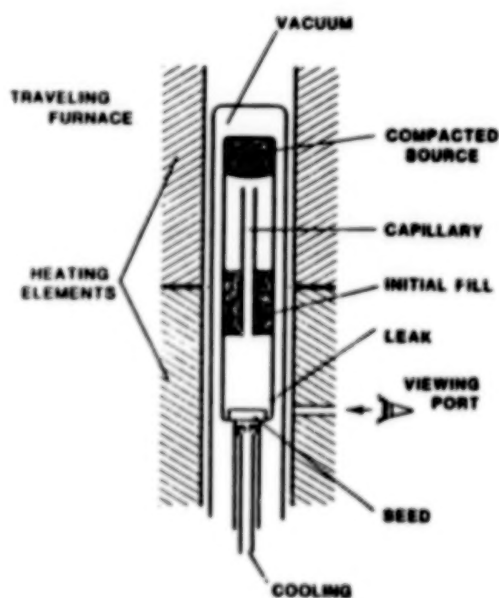
**Vapor Crystal Growth Technology**

Franz E. Rosenberger and Francis C. Weisling

University of Alabama Center for Microgravity and Materials Research (support by Boeing)

Contract: NAS3-25361, Lewis Research Center, Walter Duval

**EXPERIMENT DESCRIPTION**



**Essential Elements of Congruent (Diffusionless)**

**Growth Technique:**

- Semi-closed (leaky) ampoule
- Predetermined (viscous) transport rates and minimization of rate fluctuations
- No sealing of ampoule required
- Initial purification of source material
- Continuous purification, but possible stoichiometry shifts
- Predetermined crystal location, size and orientation
- Observability and, hence, controllability of seeding
- Temperature profile readily adjustable and, hence, expedient determination of optimum growth conditions

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IN-SPACE SYSTEMS

Out-Reach

Materials Processing

*Vapor Crystal Growth Technology*

Franz E. Rosenberger and Francis C. Wesling

University of Alabama Center for Microgravity and Materials Research (support by Boeing)

Contract: NAS3-25361, Lewis Research Center, Walter Duval

**TASK SCHEDULE/PRODUCTS**

	'88				'89				'90			
	O	N	D	J	F	M	A	M	J	J	A	S
<b>EXPERIMENT TECHNICAL REQUIREMENTS</b>												
Definition of Experiment Requirements												
Choice of Specific Crystal Material												
Supporting Research												
Modelling of heat transfer, thermometry												
Modelling of vapor transport conditions												
Prototype System and Experiments												
Component design, building and/or procurement												
System assembly and testing												
Development of (semi-automated) growth procedure												
Technical Requirements Report												
<b>EXPERIMENT CONCEPTUAL DESIGN (For Phase II)</b>												
Definition of Specific In-Space Technology Experiment												
Identification of Support Equipment Requirements												
Hardware Accommodation Study												
Engineering Trade Study												
Functional Diagram												
<b>IMPLEMENTATION PLAN AND COST ESTIMATE (For Phase II)</b>												
<b>REVIEWS AND REPORT</b>												
Quarterly Technical Status Reports												
Semiannual Progress Report												
Final Report (principal deliverable)												
<b>MEETINGS</b>												
OAST IN-STEP (Atlanta)												
Review Technical Requirements (UAH)												
Review Hardware Concept (LeRC)												
Final Review (LeRC)												



Out-Reach

## HUMANS IN SPACE

Out-Reach

Human Performance

### *Enhancement of In-Space Operations Using Spatial Perception Auditory Referencing (SPAR)*

Dr. Robert H.L. Blanka, Dr. Jole P. Jones, and Dr. Yasuhiro Tongue

University of California, Irvine

Contract: NAS2-12834, Ames Research Center, Elizabeth M. Wenzel

#### OBJECTIVES:

DETERMINE THE FEASIBILITY OF USING DIRECTIONALLY CODED AUDITORY TRANSMISSION FOR THE  
ENHANCEMENT OF IN-SPACE OPERATIONS BY PROVIDING DIRECTIONALLY CODED SOUND FOR:

##### 1) ADVANCED LIFE SUPPORT

- \* DIRECTIONALLY CODED PROXIMITY / THREAT ALERT
- \* AUDITORY DISPLAY OF AIR LOCKS, CO-WORKERS EVA, ROBOTICS AND PARTS
- \* IMPROVED ASTRONAUT VIGILANCE, JUDGEMENT AND WORK EFFICIENCY EVA

##### 2) DIAGNOSTIC AND DATA SYSTEM (ALGORITHMS)

- \* KINEMATIC REFERENCING OF EVA ASTRONAUTS, ROBOTS AND MATERIALS
- \* PROVIDE DIRECTIONAL INFORMATION TO SAFETY OFFICERS
  - ON BOARD
  - SPACE STATION CONTROL FACILITY

##### 3) LIFE SUPPORT AND SAFETY

- \* TREATMENT STRATEGY FOR SPACE ADAPTATION SYNDROME

##### 4) OTHER BENEFITS

- \* IMPROVED QUALITY OF AUDITORY COMMUNICATIONS
- \* CUSTOMIZED ENTERTAINMENT FOR ASTRONAUTS

#### BACKGROUND:

- \* NATURAL SOUND CONVEYS THE DIRECTION, DISTANCE AND "SIZE" OF THE SOURCE
- \* DIRECTIONAL CUES ARE LOST WHEN SOUND IS HEARD OVER EARPHONES
- \* SOUND CAN BE ELECTRONICALLY PROCESSED, FOR TRANSMISSION OVER EARPHONES, TO REINSTATE DIRECTIONAL CUES
- \* SOUND PROCESSING CAN BE:
  - VIRTUAL (E.G., VOICES HEARD AS COMING FROM THE DIRECTION OF PERSON SPEAKING)
  - CODED (E.G., TONES INDICATING LOCATION OF AIRLOCKS, ROBOTS, PARTS OR GEOCENTRIC REFERENCE)
- \* MINIMUM TRAINING IS REQUIRED TO EXTRACT DIRECTIONAL CUES FROM PROCESSED SOUND TRANSMISSIONS

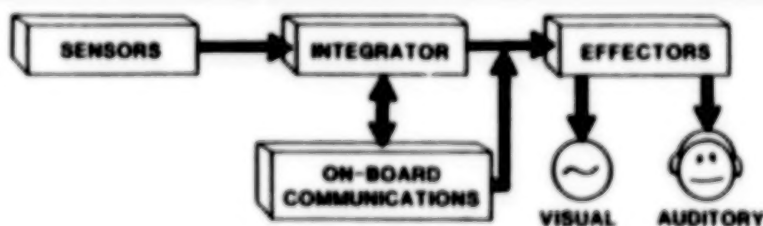
Out-Reach	<b>HUMANS IN SPACE</b> Human Performance	Out-Reach
<b>Enhancement of In-Space Operations Using Spatial Perception Auditory Referencing (SPAR)</b>		
Dr. Robert H.L. Blanks, Dr. Jole P. Jones, and Dr. Yasuhiro Torigoe		
University of California, Irvine		
Contract: NAS2-12834, Ames Research Center, Elizabeth M. Wenzel		

### TECHNOLOGY REQUIRED FOR SOUND LOCALIZATION:

- KINEMATIC REFERENCING (SENSOR SYSTEMS) ASTRONAUT BODY AND HEAD POSITION, ROBOTS AND PARTS
- OPTIMUM SOUND SYSTEM, HELMET AND HEADPHONE DESIGN
- INTERFACE TO COMPUTER SYSTEMS/COMMUNICATIONS

### NEED FOR SPACE EXPERIMENT:

- CONSTRUCTION AND MAINTENANCE OF SPACE STATION REQUIRES UNPRECEDENTED AMOUNTS OF EVA ACTIVITY
- THE BENEFITS OF DIRECTIONALLY CODED SOUND ON ASTRONAUT PERFORMANCE EVA (IMPROVED SAFETY, WORK EFFICIENCY, VIGILANCE) ARE BEST ASSESSED OPERATIONALLY AND UNDER MICROGRAVITY CONDITIONS
- SPACE ADAPTATION SYNDROME (SAS) WILL BE A PROBLEM GIVEN FREQUENT CREW CHANGES FOR CONSTRUCTION AND SERVICING OF THE STATION
- TREATMENT STRATEGIES FOR SAS MUST ULTIMATELY BE TESTED IN MICROGRAVITY OF SPACE



THREE DIMENSIONAL REFERENCING OF ASTRONAUT HEAD POSITION & ORIENTATION RE. SPACECRAFT ACHIEVED BY:

- ON-BOARD INERTIAL NAVIGATION SYSTEMS
- UPGRADE OF 'COMMON TRACKING SYSTEM' TO INCLUDE ASTRONAUT POSITION & ORIENTATION
- NEW APPLICATION FOR LOCAL NAVIGATION SYSTEMS

- \* LASER DOCKING SYSTEM
- \* FIBER OPTIC INERTIAL GYROSCOPES

STAND ALONE HARDWARE/FIRMWARE SYSTEM SINGLE BOARD - MULTIPROCESSOR

EVA: SMALL CONTROLLER BOARD ON EMU

IVA/GROUND CONTROL: INTERFACE/ADD ON TO ON BOARD COMPUTER SYSTEM

FULL COMPATIBILITY WITH ON BOARD /GROUND CONTROL SYSTEMS

\* AUDITORY DISPLAY OF:

- WARNING SIGNALS (O<sub>2</sub> LEVELS, PROXIMITY ALERT)
- ACOUSTICAL POINTING (AIRLOCKS, PARTS, ETC.)
- 3-D SOUND (CODED TRANSMISSIONS BETWEEN ASTRONAUTS AND SAFETY OFFICER)

SIMULTANEOUS VISUAL DISPLAY FOR BENEFIT OF ON BOARD SAFETY OFFICER

\* DISPLAY MODES 1 & 2 COULD BE ACHIEVED WITH FIXED SPEAKER IN EMU HELMET OR VIA EAR INSERTS. 3-D SOUND (3 ABOVE) REQUIRES FIXED MULTIPLE SPEAKERS OR HEADPHONE.

Out-Reach

**HUMANS IN SPACE**  
Human Performance

Out-Reach

***Enhancement of In-Space Operations Using Spatial Perception Auditory Referencing (SPAR)***

Dr. Robert H.L. Blanks, Dr. Jole P. Jones, and Dr. Yasuhiko Terigoe  
University of California, Irvine

Contract: NAS2-12834, Ames Research Center, Elizabeth M. Wenzel

**SCHEDULE**

MONTHS	1988						1989					
	6	7	8	9	10	11	12	1	2	3	4	5
1. EVALUATE COMMERCIAL SOUND SYSTEM												
2. EVALUATE SPAR TECHNOLOGY												
3. EVALUATE EXISTING SENSOR TECHNOLOGY												
4. BUILD AND ASSEMBLE PROTOTYPE												
5. SOFTWARE DEVELOPMENT												
6. BENCH TEST 4 & 5 ABOVE FOR EXPERIMENTS												
7. PSYCHOACOUSTIC EXPERIMENTS												
8. UNDERWATER ORIENTATION EXPERIMENTS												
9. MODIFY PROTOTYPE (UNDERWATER EXP.)												
10. PREPARE DOCUMENTATION TO NASA												

Out-Reach

**HUMANS IN SPACE**  
**Closed-Loop Life Support**

Out-Reach

***Definition Of a Microbiological Monitor for Application in Space Vehicles***

Malvin V. Kilgore, Jr., and Dr. Robert J. Zahorchak  
University of Alabama in Huntsville, Consortium For the Space Life Sciences  
Contract: NAS9-17963, Johnson Space Center, Dr. Duane Pierson

**EXPERIMENT OBJECTIVES:**

**PHASE I**

- Identify and Evaluate current methodologies for microbial monitoring
- Determine the Feasibility of Developing the Hardware for Space Applications
- Develop a Method for the Application of Microbiological Monitoring in Space
- Develop a Conceptual Design and Functional Diagram
- Prepare a Cost Estimate Regarding the Development Phase
- Define the Experimental Parameters to be Evaluated on Future STS Missions

**PHASE II**

- Thorough Evaluation of the Candidate Methodologies
- Development of Prototype Hardware
- Extensive Ground Based Evaluation of Hardware and Methodology
- In Flight Experiments

**BACKGROUND**

- |   |  |
|---|--|
| • Necessity for Microbiology Monitoring<br>Closed System Environment<br>Increased Duration Missions<br>Increased Distances<br>Potential for Immuno Compromised Crew<br>Experiments and Hardware | • Unique Requirements<br>Microgravity Conditions<br>Multiple Sample Handling<br>Power, Weight, Volume<br>Analysis Time |
| • Current Methodologies<br>Particulate Detection<br>Culture Techniques<br>Indicator Organisms   | • Specifications<br>Water<br>Air<br>Microgravity   |

**TECHNOLOGY NEED**

- No Commonly used Near Real Time Monitor Currently Available

**JUSTIFICATION**

- Assurance of Performance
- Bacterial Physiology Significantly Different in Space

Out-Reach

**HUMANS IN SPACE**  
**Closed-Loop Life Support**

Out-Reach

***Definition Of a Microbiological Monitor for Application in Space Vehicles***

Malvin V. Kilgore, Jr., and Dr. Robert J. Zaherchak  
University of Alabama in Huntsville, Consortium For the Space Life Sciences  
Contract: NAS9-17983, Johnson Space Center, Dr. Duane Pierson

**EXPERIMENT DESCRIPTION:**

**PHASE I**

- Definition and Design of a Near Real-Time Microbiological Monitor for Space Applications

**PHASE II**

- Development and Evaluation of Performance of a Microbiological Monitor Under Microgravity and Other Conditions Imposed by Space

**CRITERIA FOR FLIGHT EXPERIMENT**

- Should Provide Information Required for the Development of a RTMM
- Should Demonstrate Proof of Concept Under Microgravity Conditions
- Should be Self Contained and Require Little Crew Support
- Experimental Design Should be such that Results/Products can be Analyzed/Retrieved on the Ground

**TECHNICAL APPROACH**

**METHOD EVALUATION AND TRADE STUDIES**

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• Technical                             <ul style="list-style-type: none"> <li>Primary                                     <ul style="list-style-type: none"> <li>Sensitivity</li> <li>Time</li> <li>Maturity</li> <li>Applications</li> </ul> </li> <li>Secondary</li> </ul> </li> <li>• Engineering                             <ul style="list-style-type: none"> <li>Power</li> <li>Weight</li> <li>Volume</li> <li>Expendables</li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>• Feasibility                             <ul style="list-style-type: none"> <li>Precision</li> <li>Compatibility</li> <li>Complexity</li> <li>Development</li> </ul> </li> <li>• Cost</li> </ul> |
|---|--|

EXTENSIVE GROUND BASED EVALUATION OF METHODOLOGY

DEVELOPMENT OF PROTOTYPE AND GROUND BASED STUDIES

PROOF OF CONCEPT (IN FLIGHT)

EVALUATION OF HARDWARE (IN FLIGHT)



Out-Reach

# HUMANS IN SPACE Closed-Loop Life Support

Out-Reach

## Definition Of a Microbiological Monitor for Application in Space Vehicles

Malvin V. Kilgore, Jr., and Dr. Robert J. Zahorczak  
University of Alabama in Huntsville, Consortium For the Space Life Sciences  
Contract: NAS9-17963, Johnson Space Center, Dr. Duane Pierson

### CHARACTERISTICS OF A NEAR REAL TIME MICROBIOLOGICAL MONITOR

- It Should be Adaptable to Water, Air and Surfaces
- It Should be Reliable and Require Little Maintenance
- It Should be Rapid
- It Should be Self-Contained and Require Minimum Crew Support
- It Should provide for Crew and Ground Support Interactions
- It Should Lead itself to Improvements and Modifications toward both Quantitative and Qualitative Monitor
- It Should be ready for Incorporation Aboard SS Freedom

### SUMMARY OF RESULTS

- Identified Approximately 30 Methodologies having Potential Application to Microbiological Monitoring
- Approximately One-third of these met the Primary Requirements
- Five Highest Candidates from Secondary Screening chosen for Further Evaluation
- Engineering Trade Studies Currently Underway
- Feasibility Studies Currently Underway
- Conceptual Design and Functional Diagrams

### SCHEDULE

PHASE I												PHASE II											
1988				1989				1990				1991				1992							
J	J	A	S	O	N	D	I	F	M	A	M	J	J	A	S	O	N	D	I	F	M	A	M

REVIEW

DESIGN

EVALUATION

REVIEW

DESIGN

EVALUATION

DEFINITION

DEVELOPMENT

FLIGHT EXPERIMENT

Out-Reach

**HUMANS IN SPACE  
Closed-Loop Life Support**

Out-Reach

***Design Of a Closed-Loop Nutrient Solution Delivery System for CELSS Application***

Dr. Steven H. Schwartzkopf and Mr. Mal W. Olsson  
Lockheed Missiles & Space Co., Boeing Aerospace Co.  
Contract: NAS9-17981, Johnson Space Center, Dr. Halice S. Cullingford

**EXPERIMENT OBJECTIVE (PHASE I)**

**TO DEVELOP A CONCEPTUAL DESIGN FOR A CLOSED-LOOP FLUID HANDLING SYSTEM THAT IS CAPABLE OF MONITORING, CONTROLLING, AND SUPPLYING NUTRIENT SOLUTION TO HIGHER PLANTS UNDER MICRO-GRAVITY ENVIRONMENTAL CONDITIONS IN A CELSS APPLICATION**

**BACKGROUND/TECHNOLOGY NEED**

**THE TRANSFER, STORAGE AND CONTROL OF LIQUIDS UNDER MICRO-GRAVITY CONDITIONS IS A UBIQUITOUS PROBLEM FOR SPACE FLIGHT. FOR ADVANCED LIFE SUPPORT (CELSS) APPLICATIONS, THE HANDLING OF FLUIDS AND THE CONTROL OF FLUID COMPOSITION ARE TWO OF THE MAJOR PROBLEMS.**

**THE TECHNOLOGY TO SOLVE THESE PROBLEMS WILL LEAD TO A SIGNIFICANT REDUCTION IN THE AMOUNTS OF LIFE-SUSTAINING MATERIALS CARRIED ON MANNED MISSIONS; THUS DECREASING THE ECONOMIC COST OF THESE MISSIONS.**

**EXPERIMENT DESCRIPTION**

**THE PROTOCOL OF THIS EXPERIMENT IS DESIGNED TO:**

- 1) MEASURE SOLUTION MONITORING CAPABILITIES UNDER MICRO-GRAVITY CONDITIONS**
- 2) MEASURE SOLUTION COMPOSITION CONTROL CAPABILITIES UNDER MICRO-GRAVITY CONDITIONS**
- 3) MEASURE THE CAPABILITY OF THREE DIFFERENT NUTRIENT SOLUTION DELIVERY/RECOVERY SYSTEMS TO PROVIDE WATER AND NUTRIENTS TO HIGHER PLANTS UNDER MICRO-GRAVITY CONDITIONS**
- 4) MEASURE THE CAPABILITY TO CONDENSE, COLLECT AND RECYCLE WATER VAPOR**

*CELSS: Controlled Ecological Life Support Systems*

Out-Reach

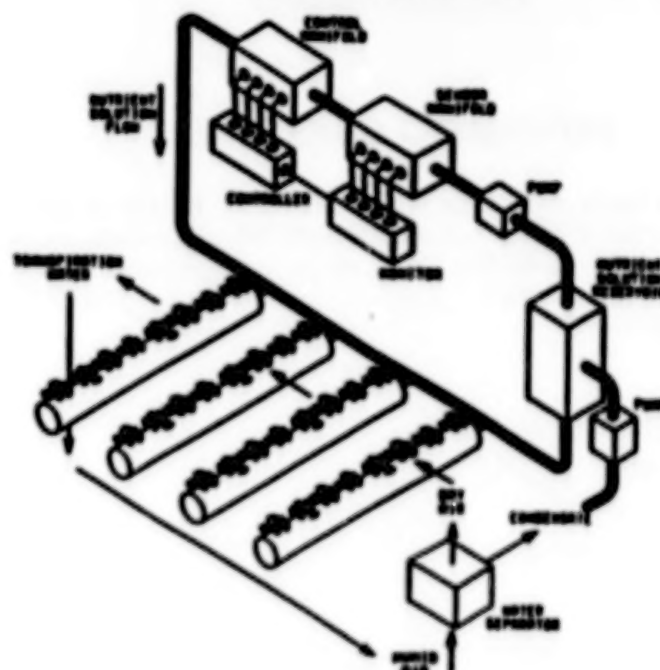
**HUMANS IN SPACE**  
Closed-Loop Life Support

Out-Reach

**Design Of a Closed-Loop Nutrient Solution Delivery System for CELSS Application**

Dr. Steven H. Schwartzkopf and Mr. Mel W. Olson  
Lockheed Missiles & Space Co., Boeing Aerospace Co.  
Contract: NAS9-17981, Johnson Space Center, Dr. Halice S. Cullingford

**CONCEPT DRAWING**



**PROJECT SCHEDULE**

TITLE: Closed Loop Nutrient Delivery		FUNDING:		RESPONSIBILITY: S. Schwartzkopf				DATE: 12-1-87											
CALENDAR YEARS		1988												1989					
CALENDAR MONTHS		NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
1. Requirements Review & Definition		Y		Y		Y													
2. Requirements Review		Y				Y													
3. Subsystem Conceptual Design		Y												Y					
4. Preliminary Design Review														Y					
5. System Integration & Design														Y				Y	
6. Final Design Review																		Y	
7. Final Report																		Y	

Out-Reach

**HUMANS IN SPACE**  
Closed-Loop Life Support

Out-Reach

***Impact of Low Gravity on Water Electrolysis Operation***

Franz H. Schubert  
Life Systems, Inc.

Contract: NAS9-17986, Johnson Space Center, Albert Behrend

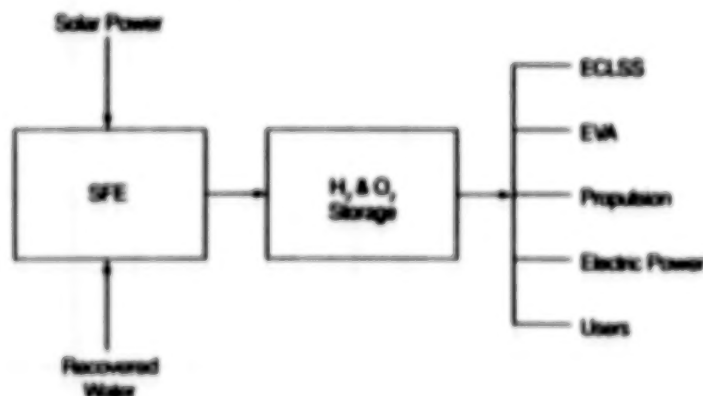
**EXPERIMENT OBJECTIVE**

Investigate ways a low-G environment may improve static feed water electrolysis (SFE) performance based on the hydrophobic/philic cell components, and fluid and thermal flows within the cell. The results will be used to improve static feed electrolysis process efficiency for:

- Life Support
- Propulsion
- EMU O<sub>2</sub> Bottle Recharge
- Energy Storage
- Industry

**BACKGROUND/TECHNOLOGY NEED**

- Hydrogen and Oxygen (H<sub>2</sub>O) are key to survival for humans in deep space
- Static Feed Electrolysis (SFE) is a key technology for H<sub>2</sub>O based economy
- Electrochemical processes are key to industrialization of space



Out-Reach

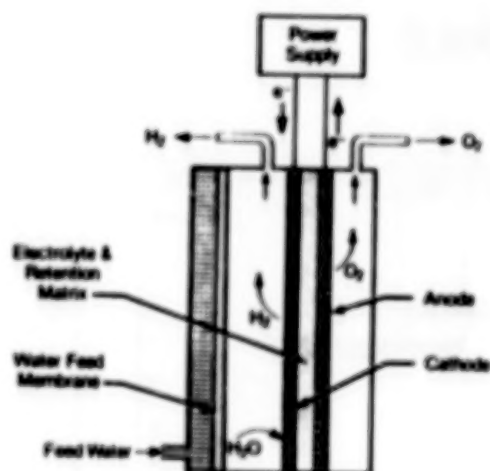
**HUMANS IN SPACE**  
Closed-Loop Life Support

Out-Reach

**Impact of Low Gravity on Water Electrolysis Operation**

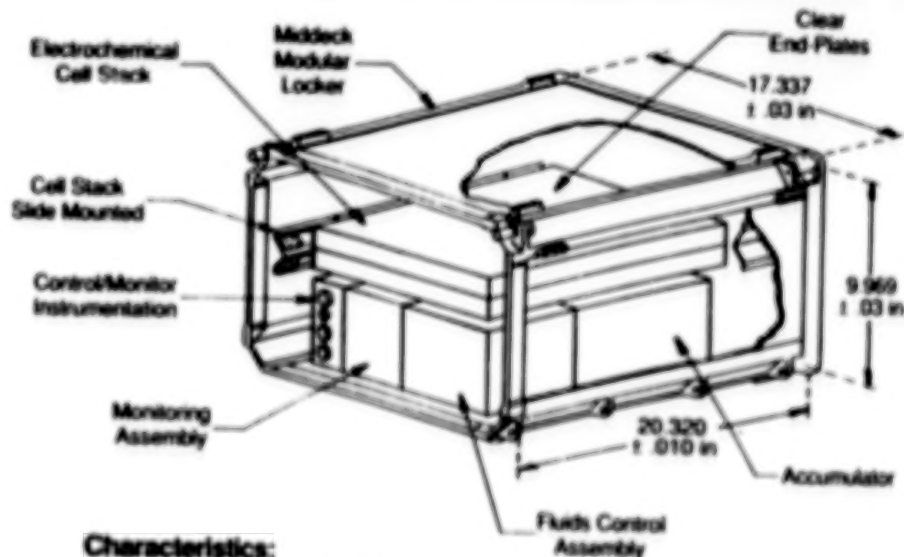
Franz H. Schubert  
Life Systems, Inc.

Contract: NAS9-17966, Johnson Space Center, Albert Behrend



**EXPERIMENT DESCRIPTION**

The experiment apparatus will provide the ability to study the two major processes which occur within an SFE. The first is the electrochemical process of water electrolysis in an alkaline electrolyte. The second process is the static addition of water to the cell and diffusion to the electrolysis site. The experiment will be self-contained except for a power supply requirement. Conventional instrumentation including pressure and temperature sensors will be required.



**Characteristics:**

Dimensions, in: 9 x 16 x 20  
Weight, lb : 30



Out-Reach

**HUMANS IN SPACE**  
Closed-Loop Life Support

Out-Reach

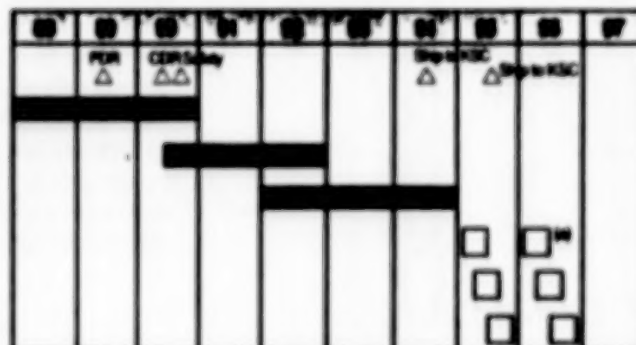
*Impact of Low Gravity on Water Electrolysis Operation*

Franz H. Schubert  
Life Systems, Inc.

Contract: NAS9-17966, Johnson Space Center, Albert Behrend

## MASTER SCHEDULE

Formal Reviews  
System Design  
Fabrication and Assembly  
Testing  
Mission & Flight Operations  
Data Analyses  
Refurbishment

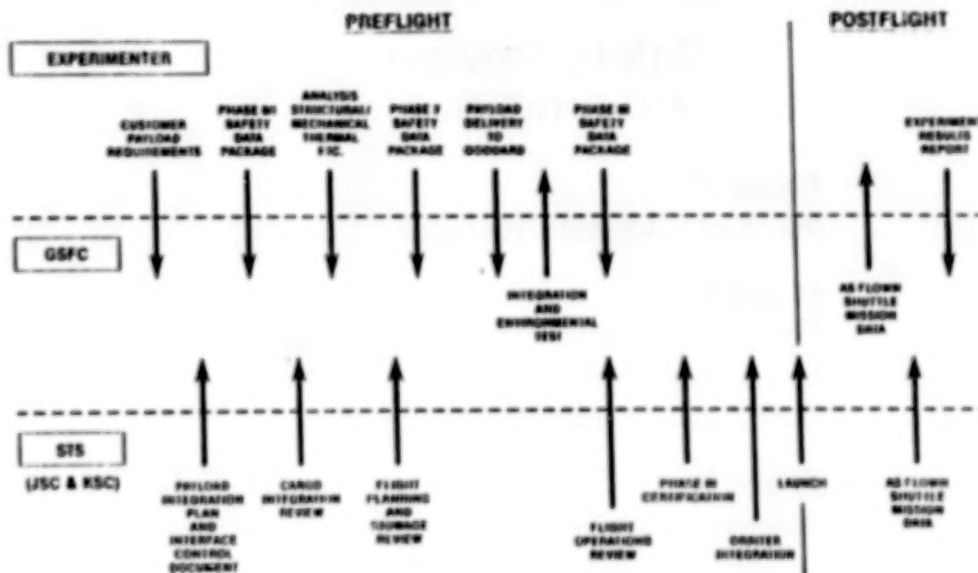


(a) Experiment equipment can be refurbished (and modified, if necessary) and flown again to investigate other areas of electrochemical phenomena in low gravity.

# **HUMANS IN SPACE** Experiment Integration Process *Payload Integration Overview*

Clarke R. Prouty  
Goddard Space Flight Center, Special Payloads Division

## **In-Step Payload Milestones**



## **Payload Requirements**

### **Payload Requirements**

- Mid-Deck Payloads PIP
- Complex Autonomous Payloads (CAP) Payload Accommodation Requirements (PAR)
- Hitchhiker Payloads Customer Payload Requirements (CPR)

- Experiment Description
- Hardware Description
- Operational Scenario

### **Support**

- Mission Manager
- Safety Officer
- Integration
- Pre and Post Flight

**HUMANS IN SPACE**  
Experiment Integration Process  
*Payload Integration Overview*

Clarke R. Prouty  
Goddard Space Flight Center, Special Payloads Division

**Safety Review  
And Certification**

- Phase 0  
Informal - Identify Hazards
- Phase I  
Formal - Assess Preliminary Design  
Evaluate preliminary hazard controls,  
Verification methods
- Phase II  
Assess Final Design  
Concur on hazard controls,  
Safety verification Methods
- Phase III  
Formal - Approve Safety Assessment Report  
Review Safety Compliance Data Package  
Identify Open Safety Items

**NASA Documents**

- PIP
- PIP Annexes
- ICD

**HUMANS IN SPACE**  
Experiment Integration Process  
*Payload Integration Overview*

Clarke R. Prouty  
Goddard Space Flight Center, Special Payloads Division

**Payload Integration**  
Carrier

- Fit Checks and Assembly Loading consumables
- Final testing
- System Checkout

**Payload Integration**  
Carrier

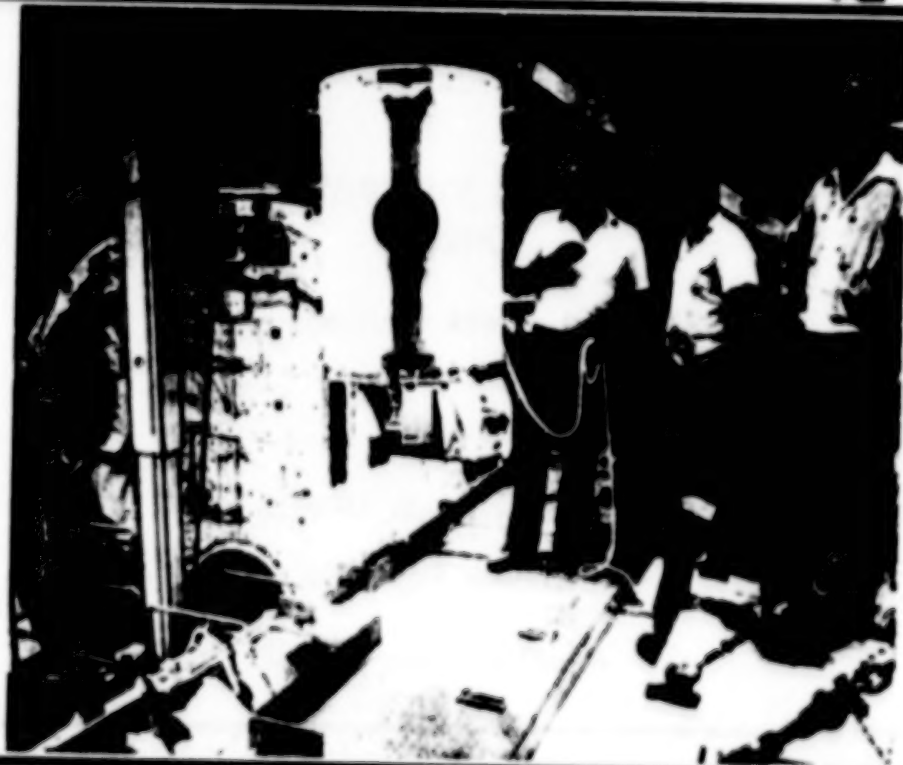
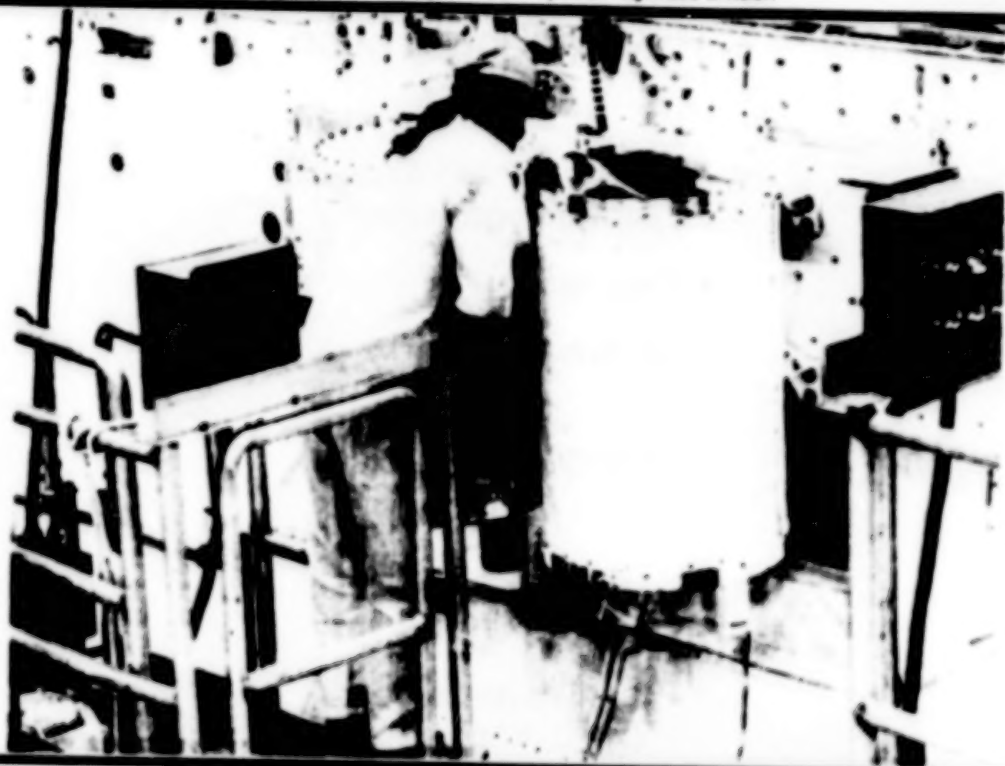
- Mid - Deck Payloads  
JSC
- CAP Payloads  
GSFC, KSC
- Hitchhiker Payloads  
GSFC, KSC

**Payload Integration**  
Orbiter

- Mid - Deck Payloads  
KSC
- CAP Payloads  
KSC  
Adapter Beam, MPESS
- Hitchhiker Payloads  
KSC  
Adapter Beam, MPESS

**HUMANS IN SPACE**  
Experiment Integration Process  
*Payload Integration Overview*

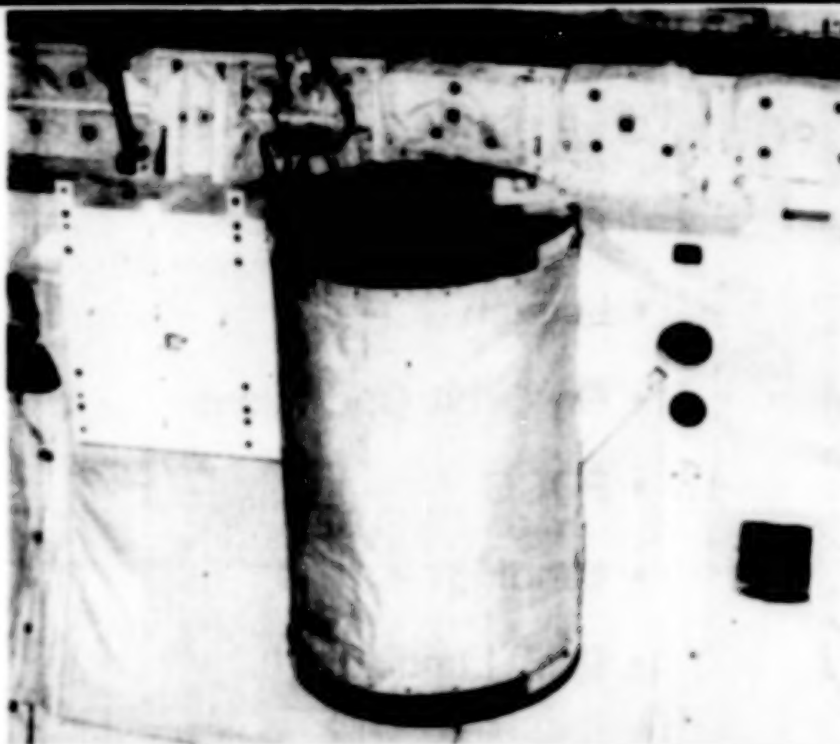
Clark R. Prouty  
Goddard Space Flight Center, Special Payloads Division





**HUMANS IN SPACE**  
Experiment Integration Process  
*Payload Integration Overview*

Clark R. Prouty  
Goddard Space Flight Center, Special Payloads Division



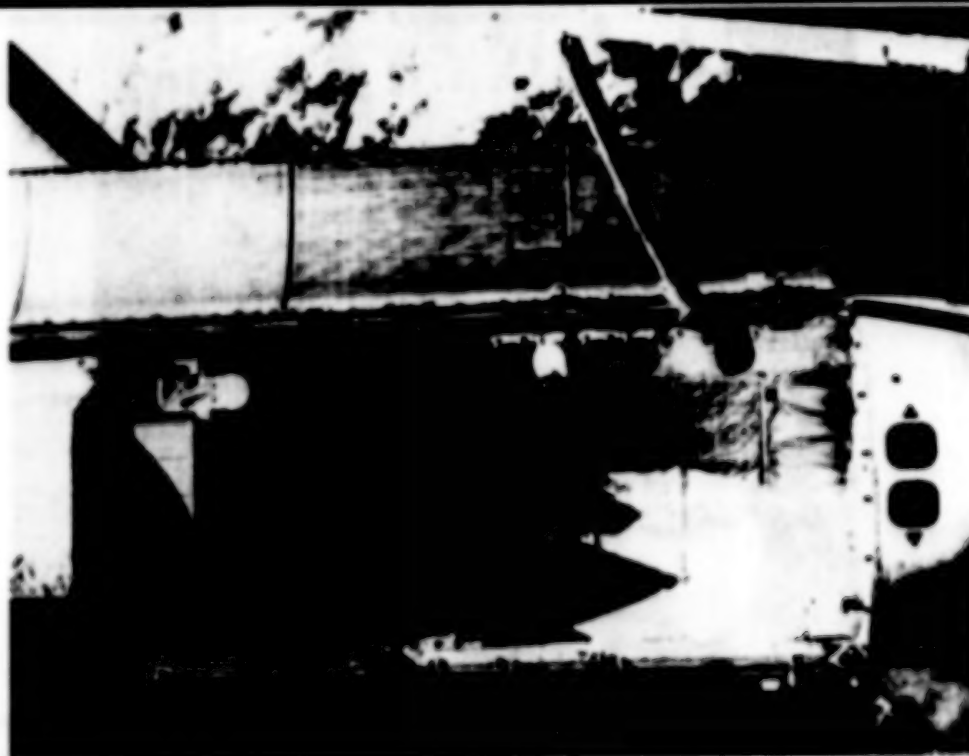
**HUMANS IN SPACE**  
Experiment Integration Process  
*Payload Integration Overview*

Clarke R. Prouty  
Goddard Space Flight Center, Special Payloads Division

## Mission

- Launch
- On Orbit Operations
- POCC
- Landing
- Post Landing

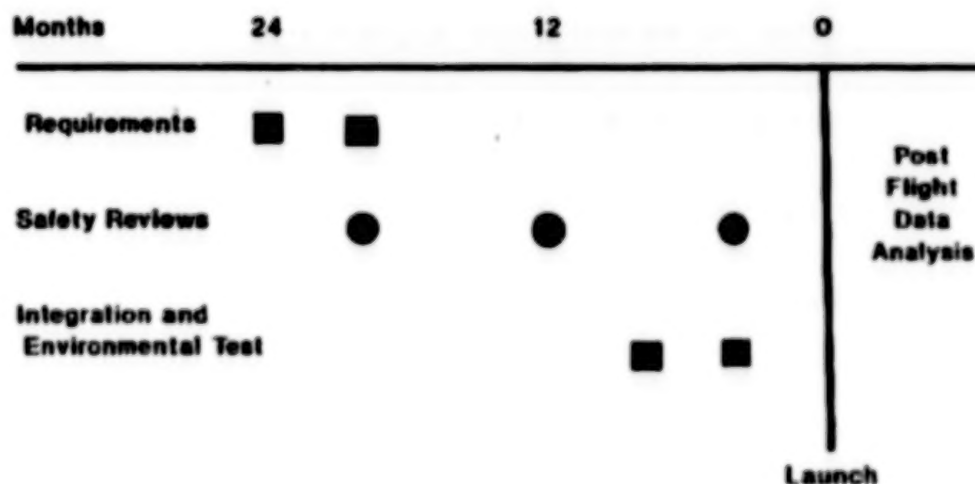
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**HUMANS IN SPACE**  
Experiment Integration Process  
*Payload Integration Overview*

Clarke R. Prouty  
Goddard Space Flight Center, Special Payloads Division

## In-Step Payload Review and Integration Schedule



## In-Step Payloads The Future

- Current Flight Opportunities on Shuttle
- Will expand to Expendable Launch Vehicles
- Begin with available Shared Flights
- May Fund Dedicated OAST ELV
- Eventual Space Station Experiments

**HUMANS IN SPACE**  
**Space Shuttle System Payload Integration Process**  
***NSTS Integration and Operations***

John C. O'Laughlin  
Johnson Space Center, Spacecab & Middeck Integration Office

THE SPACE SHUTTLE SYSTEM PAYLOAD INTEGRATION PROCESS OVERVIEW

- NATIONAL SPACE TRANSPORTATION SYSTEM (NSTS) ORGANIZATION
- SPACE SHUTTLE SYSTEM DESCRIPTION
- PAYLOAD INTEGRATION PROCESS
- SCHEDULES/MANIFESTING

NSTS ORGANIZATION

- NASA HEADQUARTERS
  - OVERALL MANAGEMENT OF THE NSTS
  - MANAGES TRANSPORTATION SERVICES
    - FLIGHT SCHEDULING
    - REQUEST FOR FLIGHT ASSIGNMENT (NASA FORM 1620)
    - NEGOTIATION AND IMPLEMENTATION (POLICY, LEGAL, BUSINESS AND FINANCIAL ASPECTS)
- JSC
  - MANAGES THE DEVELOPMENT AND OPERATIONS OF THE SPACE SHUTTLE
  - MANAGES TECHNICAL INTEGRATION OF PAYLOAD INTO THE STS SHUTTLE
    - WORKING GROUPS FOR ENGINEERING AND OPERATIONS PLANNING
    - DEFINE INTERFACE AND OPERATIONAL REQUIREMENTS
    - IDENTIFY, DEFINE, AND INTEGRATE ENGINEERING TASKS

**HUMANS IN SPACE**  
**Space Shuttle System Payload Integration Process**  
***NSTS Integration and Operations***

John C. O'Laughlin  
Johnson Space Center, Spacelab & Middeck Integration Office

- **KSC**
  - LAUNCH AND LANDING SUPPORT FOR THE SHUTTLE
  - IMPLEMENTS ACTIVITIES ASSOCIATED WITH PREPARING THE SPACE SHUTTLE AND ITS PAYLOADS
    - PAYLOAD PROCESSING
    - LAUNCH SUPPORT
    - LANDING
    - POST-FLIGHT SERVICES
- **MSFC**
  - RESPONSIBLE FOR MANAGING THE DEVELOPMENT OF:
    - SOLID ROCKET BOOSTERS
    - SPACE SHUTTLE MAIN ENGINES
    - EXTERNAL TANK
    - SPACELAB MODULES AND PALLETS
- **GSFC**
  - RESPONSIBLE FOR MANAGING:
    - COMMUNICATIONS NETWORK
    - SPACE FLIGHT TRACKING DATA NETWORK
    - GET AWAY SPECIAL (GAS) PROGRAM
    - OTHER SMALL PAYLOAD CARRIER PROGRAMS



# **HUMANS IN SPACE** **Space Shuttle System Payload Integration Process** **NSTS Integration and Operations**

John C. O'Laughlin  
Johnson Space Center, Spacelab & Middeck Integration Office

## **SPACE SHUTTLE SYSTEM**

- ORBITER
  - PAYLOAD BAY
  - MIDDECK
- SOLID ROCKET BOOSTERS
- EXTERNAL TANK
- FLIGHT CREW
  - COMMANDER
  - PILOT
  - MISSION SPECIALIST (2 OR MORE)

## **SPACE SHUTTLE SYSTEM**

### **SPACE SHUTTLE SYSTEM**

OVERALL LENGTH 145.5 FT (44.3 M)  
HEIGHT 145.5 FT (44.3 M)

### **EXTERNAL TANK**

DIAMETER 33.5 FT (10.2 M)  
LENGTH 145.5 FT (44.3 M)

### **SOLID ROCKET BOOSTERS**

DIAMETER 12.5 FT (3.7 M)  
HEIGHT 145.5 FT (44.3 M)  
THRUST (SEA LEVEL) 5.1 MILLION LB (22.8 MN)

### **ORBITER**

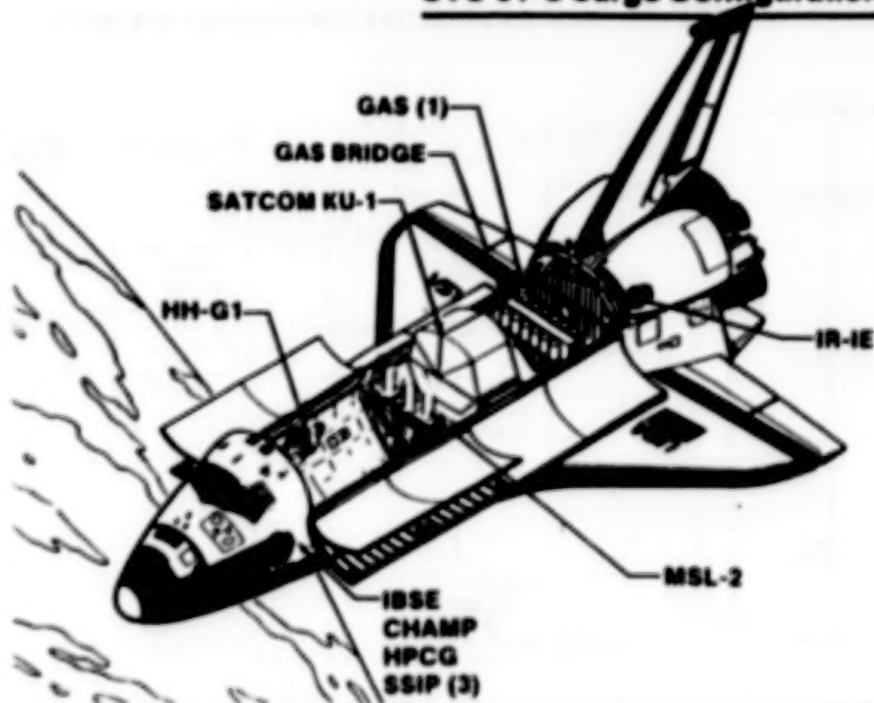
LENGTH 145.5 FT (44.3 M)  
DIAMETER 33.5 FT (10.2 M)  
TAKE-OFF WEIGHT 145,000 LB (65,760 N)  
PAYLOAD BAY 15 FT (4.5 M) BY 15 FT (4.5 M) BY 15 FT (4.5 M)  
MAIN ENGINES (3) 1,000,000 LB (444,822 N)  
- VACUUM THRUST EACH 1,000,000 LB (444,822 N)  
ORBITER (2) 1,000,000 LB (444,822 N)  
- VACUUM THRUST EACH 1,000,000 LB (444,822 N)  
- 10 ENGINES 1,000,000 LB (444,822 N)  
- 10 ENGINES 1,000,000 LB (444,822 N)  
- 10 ENGINES 1,000,000 LB (444,822 N)  
- 10 ENGINES 1,000,000 LB (444,822 N)



**HUMANS IN SPACE**  
Space Shuttle System Payload Integration Process  
*NSTS Integration and Operations*

John C. O'Laughlin  
Johnson Space Center, Spacelab & Middeck Integration Office

**STS 61-C Cargo Configuration**



**PAYLOAD INTEGRATION PROCESS OVERVIEW**

- FORMAL REQUEST FOR FLIGHT ASSIGNMENT (FORM 1628)
- DEVELOPMENT OF FORMAL AGREEMENTS
- IMPLEMENTATION OF AGREEMENTS
- PHASED SAFETY REVIEWS - FLIGHT AND GROUND EQUIPMENT
- LAUNCH
- POSTFLIGHT ACTIVITIES

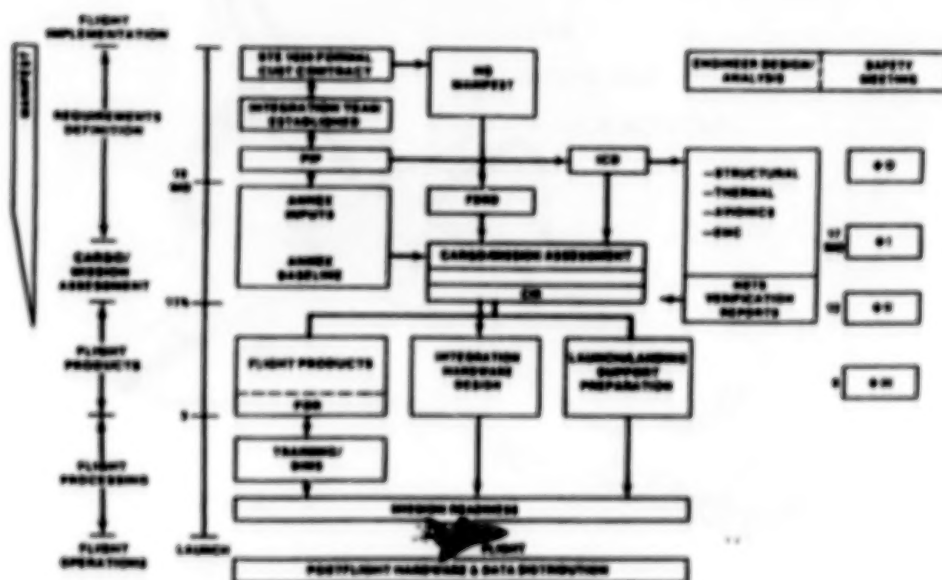
# HUMANS IN SPACE

## Space Shuttle System Payload Integration Process

### NSTS Integration and Operations

John C. O'Laughlin  
Johnson Space Center, Spacelab & Middeck Integration Office

#### PAYLOAD INTEGRATION PROCESS OVERVIEW



#### JOINT AGREEMENTS



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**NASA PAYLOAD INTEGRATION TEAM**

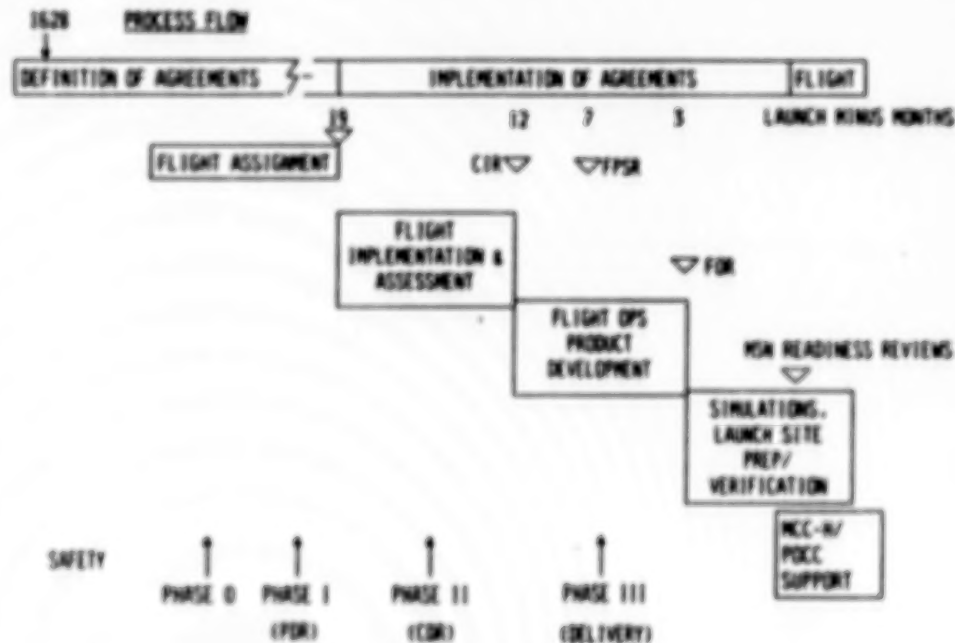
- HQ - CUSTOMER SERVICE MANAGER
  - FLIGHT SCHEDULE
  - POLICY
- JSC - PAYLOAD INTEGRATION MANAGER (PIH)
  - CUSTOMER PRIMARY POINT OF CONTACT
  - ENSURE PAYLOAD REQ. ACCURATELY DEFINED/DOCUMENTED
  - COORDINATES ENGINEERING TECHNICAL SUPPORT
- KSC - LAUNCH SITE SUPPORT MANAGER (LSSM)
  - CUSTOMER POINT OF CONTACT AT KSC
  - ENSURES PAYLOAD PROCESSING SUPPORT AT LAUNCH SITE

**PAYLOAD INTEGRATION SCHEDULE**

- FINAL MANIFESTING IS DEPENDENT ON COMPLETION OF JOINT AGREEMENTS (PIP, ICD, ANNEXES)
- COMPLETION DATES OF JOINT AGREEMENTS ARE DEPENDENT UPON CATEGORY OF PAYLOAD
- PAYLOAD INTEGRATION PROCESS FOR ALL PAYLOADS SHOULD START AS SOON AS POSSIBLE AFTER AGREEMENT TO PROCEED (ACCEPTANCE OF FORM 1628 BY NASA HEADQUARTERS)
- QUARTER SECTION TYPICAL SCHEDULE
  - PAYLOAD INTEGRATION PLAN..... DRAFT COMPLETE 2-3 MONTHS AFTER FORM 1628
  - ICD..... COMPLETE 1 MONTH AFTER PIP
  - ANNEXES..... CONSISTENT WITH START OF CIR ASSESSMENT ACTIVITY
  - SAFETY REVIEWS..... PAYLOAD DEVELOPMENT
- MISSION CAN BE DEFINED IN THE FORD WHEN JOINT AGREEMENTS ARE BASELINED PRIOR TO THE "NO LATER THAN" DATES SHOWN ON THE FOLLOWING MATRIX

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**PAYLOAD CATEGORIES**

- **PRIMARY PAYLOAD**
  - DRIVES THE OVERALL FLIGHT DESIGN
  - GENERALLY WEIGHS MORE THAN 8000 POUNDS
  - REQUIRES AT LEAST ONE-FOURTH OF PAYLOAD BAY SERVICES
- **COMPLEX SECONDARY PAYLOAD**
  - EXCEEDS NSTS ACCOMMODATIONS AS DEFINED IN APPLICABLE DOCUMENTATION
  - HAS ONE OR MORE OF THESE CHARACTERISTICS:
    - UTILIZES QUARTER-BAY PAYLOAD SERVICES
    - HAS OPTIONAL PAYLOAD BAY INTERFACES
    - HAS REQUIREMENTS WHICH DRIVE THE FLIGHT DESIGN
    - HAS UNIQUE INSTALLATION REQUIREMENTS IN THE ORBITER MIDDECK



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- **NONSTANDARD SECONDARY/SMALL PAYLOAD ACCOMMODATION (SPA)**
  - REQUIRES MINOR DEVIATIONS FROM GAS OR MIDDECK SIP AND/OR IDD
  - SPA MEETS THE SIP AND IDD REQUIREMENTS, BUT ITS COMPLEXITY REQUIRES THAT IT BE TREATED AS A NONSTANDARD SECONDARY PAYLOAD FROM A SCHEDULE PERSPECTIVE
  - DEVIATION FROM SPA STANDARDS REQUIRES THAT A PAYLOAD BE TREATED AS A COMPLEX SECONDARY
- **STANDARD SECONDARY**
  - DOES NOT EXCEED NSTS ACCOMMODATIONS AS DEFINED IN THE GAS OR MIDDECK SIP AND/OR IDD

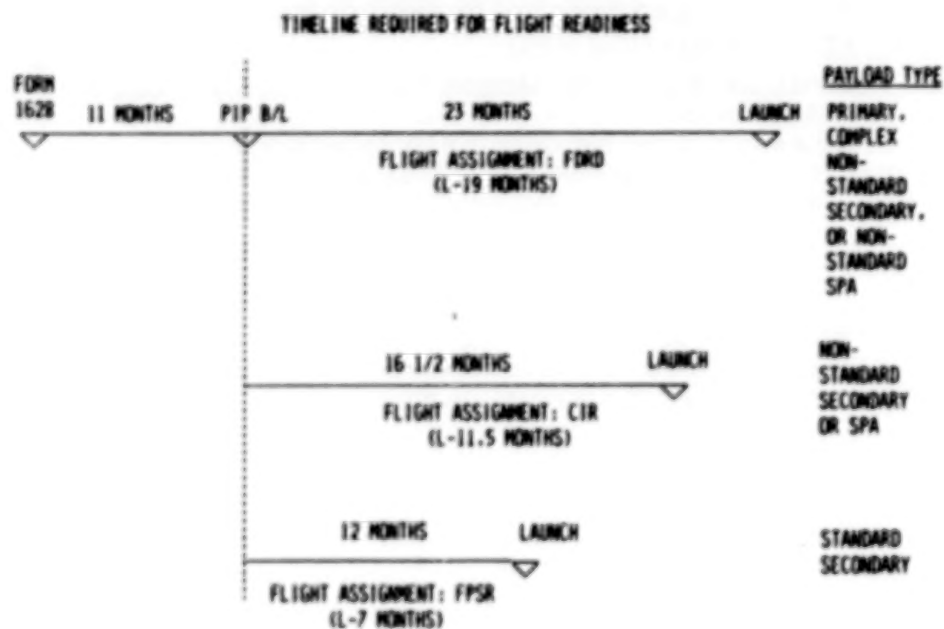
**FLIGHT ASSIGNMENT**

PAYLOAD CATEGORY	LATEST FLIGHT ASSIGNMENT	PREREQUISITES
PRIMARY	FDRD L-19 MONTHS	BASELINED* PIP AND ICD
COMPLEX SECONDARY	FDRD L-19 MONTHS	BASELINED PIP AND ICD
NONSTANDARD SECONDARY OR SPA	CARGO INTEGRATION REVIEW (CIR) L-11.5 MONTHS	BASELINED PIP AND ICD. ALL ANNEXES BASELINED EXCEPT 4 AND 9; HOWEVER, CUSTOMER SUBMITTAL OF ANNEXES 4 AND 9 IS REQUIRED.
STANDARD SECONDARY	FLIGHT PLANNING AND STOWAGE REVIEW (FPSR) L-7 MONTHS	BASELINED PIP, ICD, AND ALL ANNEXES. PHASE II SAFETY REVIEW IS REQUIRED.

\*BASELINED = SIGNED BY BOTH NSTS AND THE CUSTOMER

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**HUMANS IN SPACE**  
Space Shuttle System Payload Integration Process  
*Complex Autonomous Payload Carriers*

Clarke R. Prouty  
Goddard Space Flight Center, Special Payloads Division

**GAS / CAP**  
Similarities

- Hardware
- Facilities
- Personnel

**GAS / CAP**  
Differences

GAS	CAP
Existing Customers	Secondaries Policy
Subject to Queue	Manifested
Restrictive Interfaces	More Commands Possible Some Pointing Possible Payload Integration Plan (PIP) Longer Processing

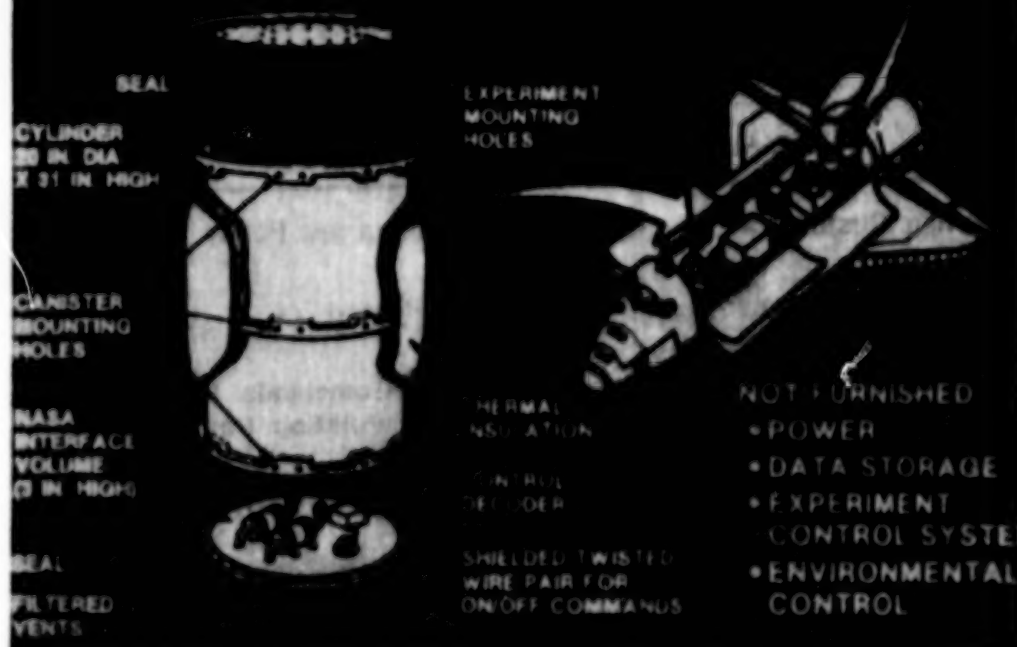
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Goddard Space Flight Center, Special Payloads Division

## Get Away Special Concept

- Encourage the use of Space by all Researchers:  
Private Individuals and Organizations
- Foster Enthusiasm in Younger Generation
- Increase Knowledge of Space
- Be Alert to Possible growth of GAS Investigation into a Prime Experiment
- Generate New Activities Unique to Space

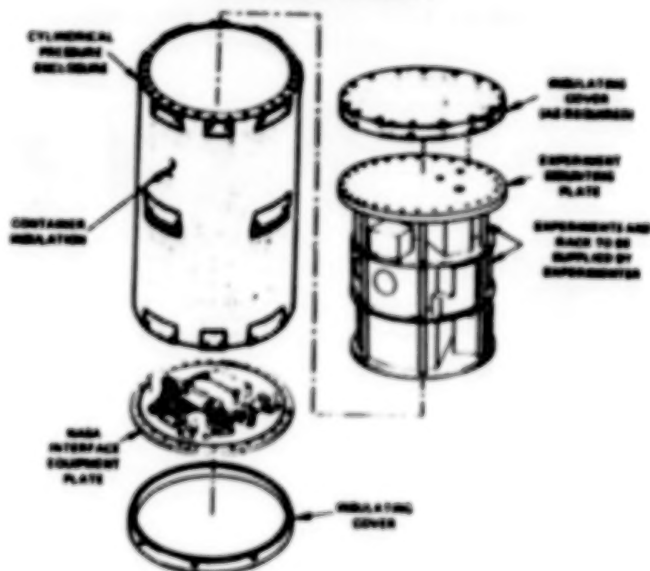
### GETAWAY SPECIAL ACCOMMODATIONS



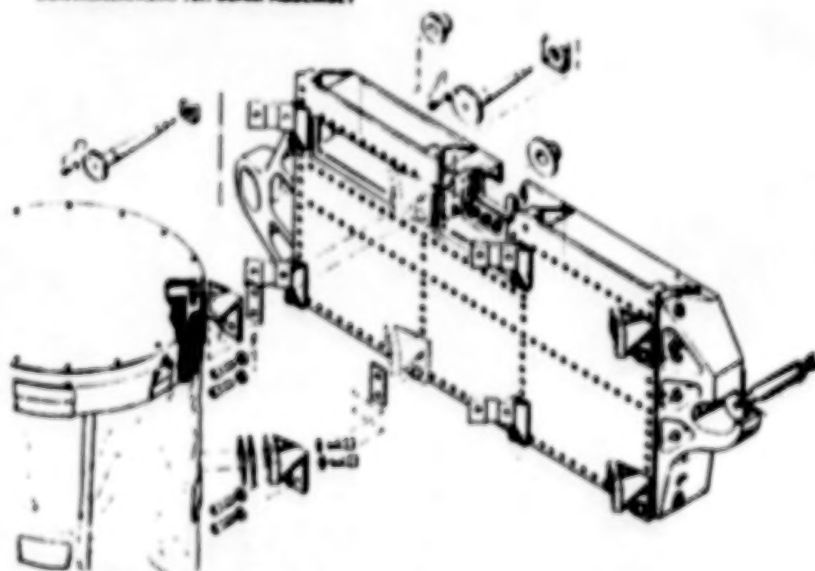
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**GET AWAY SPECIAL  
SMALL SELF-CONTAINED PAYLOADS  
CONTAINER CONCEPT**



**GET AWAY SPECIAL  
GAS  
CONTAINER/ADAPTER BEAM ASSEMBLY**

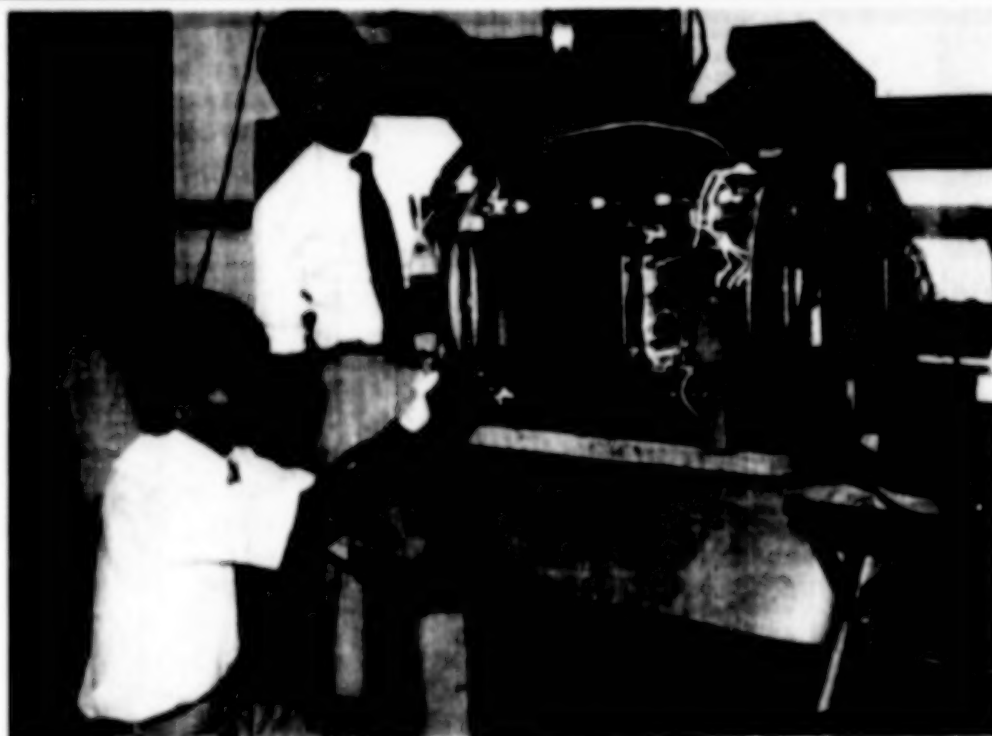
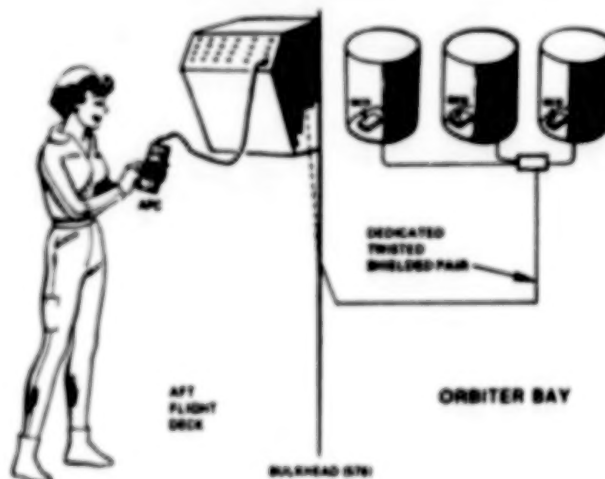




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Space Shuttle System Payload Integration Process  
*Complex Autonomous Payload Carriers*

Clark R. Prouty  
Goddard Space Flight Center, Special Payloads Division

**GET AWAY SPECIAL  
SMALL SELF-CONTAINED PAYLOADS  
CONTROL CONCEPT**



**HUMANS IN SPACE**  
**Space Shuttle System Payload Integration Process**  
***Hitchhiker Project Overview***

T.C. Goldsmith  
Goddard Space Flight Center, Shuttle Small Payloads Project

**SHUTTLE SMALL PAYLOADS PROJECT**

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- THE SHUTTLE SMALL PAYLOADS PROJECT CONTAINS THE HITCHHIKER, GET-AWAY-SPECIAL (GAS), AND COMPLEX AUTONOMOUS PAYLOADS (CAP) PROJECTS.
- HITCHHIKER INCLUDES HH-G SIDE MOUNT CARRIERS AND HH-M CROSS-BAY CARRIERS WHICH CONNECT TO ORBITER ELECTRICAL SERVICES AND ARE FLOWN UNDER THE SECONDARY PAYLOAD MANIFEST.
- GAS PAYLOADS ARE MOUNTED IN CANISTERS, DO NOT CONNECT TO ORBITER ELECTRICAL SERVICES, AND DO NOT REQUIRE SIGNIFICANT STS SUPPORT. GAS PAYLOADS ARE IN AN EXISTING TERTIARY PAYLOAD QUEUE. NO NEW RESERVATIONS ARE BEING ACCEPTED BUT EXISTING LAUNCH SLOTS MAY BE SOLD BY EXISTING RESERVATION HOLDERS.
- COMPLEX AUTONOMOUS PAYLOADS USE GAS PROJECT CARRIER EQUIPMENT, DO NOT CONNECT TO ORBITER ELECTRICAL SERVICES, BUT MAY REQUIRE STS SERVICES SUCH AS POINTING, CREW ACTIVITY, LATE ACCESS, ETC. IN EXCESS OF THOSE ALLOWED FOR GAS. CAP PAYLOADS ARE MANIFESTED UNDER THE SECONDARY PAYLOAD SYSTEM.

**HITCHHIKER PROGRAM DESCRIPTION**

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- THE HITCHHIKER PROGRAM WAS INITIATED BY THE NASA OFFICE OF SPACE FLIGHT IN 1984 TO PROVIDE A QUICK REACTION SHUTTLE CARRIER SERVICE FOR SMALL PAYLOADS. OSFC DEVELOPED THE SHUTTLE PAYLOAD OF OPPORTUNITY CARRIER (SPOC) SYSTEM TO SUPPORT THE HITCHHIKER-G PROGRAM. SPOC WAS SPECIFICALLY DESIGNED TO HAVE SIMPLE, STANDARD CARRIER TO ORBITER INTERFACES AND STANDARD, USER-FRIENDLY, CARRIER TO CUSTOMER INTERFACES TO REDUCE PAYLOAD UNIQUE INTEGRATION EFFORT REQUIRED AND THEREBY REDUCE LEAD TIME AND RECURRING COST. HITCHHIKER-G IS A FAMILY OF COMPONENTS DESIGNED TO MOUNT SMALL PAYLOADS TO THE SIDE OF THE ORBITER WITH MINIMUM TOTAL PAYLOAD WEIGHT.
- HITCHHIKER-M IS A SECOND CARRIER SYSTEM DEVELOPED BY MSFC AND CONSISTING OF A CROSS-BAY (BRIDGE) TYPE CARRIER INTENDED FOR SOMEWHAT HEAVIER PAYLOADS. IN 1987 THE HITCHHIKER-M CARRIER SYSTEM WAS COMBINED WITH THE HITCHHIKER-G PROJECT AT OSFC AND WILL FLY WITH THE SAME ELECTRICAL CUSTOMER AND ORBITER INTERFACES AS THE HITCHHIKER-G.
- HITCHHIKER IS BASICALLY AN EXTENSION OF THE STS AND IS PROVIDED AND OPERATED BY THE OFFICE OF SPACE FLIGHT AT NO COST TO A NASA USER PROVIDED ONLY STANDARD SERVICES ARE REQUIRED. EXCESS SERVICES ARE FUNDED BY THE CUSTOMER.
- HITCHHIKERS ARE FLOWN AS SECONDARY PAYLOADS UNDER THE 7/87 NASA SECONDARY PAYLOAD POLICY AND CAN FLY AS EITHER "SMALL" PAYLOADS OR STANDARD ATTACHED MIXED CARGO PAYLOADS.

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*Hitchhiker Project Overview*

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Goddard Space Flight Center, Shuttle Small Payloads Project

**HITCHHIKER MANIFESTING SITUATION**

- A NEW POLICY FOR SECONDARY PAYLOADS ON NASA SHUTTLE FLIGHTS WAS ANNOUNCED 7/28/87 AS FOLLOWS:

- ALLOCATIONS OF SECONDARY PAYLOAD SPACE BY WEIGHT (PERCENTAGE OF AVAILABLE SPACE) HAVE BEEN ESTABLISHED FOR THE VARIOUS DISCIPLINES AS FOLLOWS: (THE CORRESPONDING TOTAL PAYLOAD WEIGHT FOR EACH DISCIPLINE IS SHOWN FOR THE 4/30/88 MANIFEST.

CODE E 38	38862	SCIENCE AND APPLICATIONS
CODE C 31	33586	COMMERCIALIZATION
CODE S 10	18575	SPACE STATION TECHNOLOGY
CODE R 9	18215	SPACE TECHNOLOGY
CODE M 5	4470	STS TECHNOLOGY
CODE A 3	3886	AGENCY LEVEL
CODE X 3	3635	FOREIGN REIMBURSABLE
CODE C 1	0	DOMESTIC REIMBURSABLE
DOD 0	0	DOD (UNDER NEGOTIATION)

TOTAL 100 111883

- GET-AWAY-SPECIAL (GAS) PAYLOADS WILL FLY IN SPACE AVAILABLE AFTER ACCOMMODATING PRIMARY AND SECONDARY PAYLOADS AND WILL CONTINUE TO USE THE EXISTING QUEUE AND POLICY. NO NEW GAS PAYLOADS ARE BEING ACCEPTED.
- EMPHASIS TO BE PLACED ON MICROGRAVITY PAYLOADS OR SPACE STATION SUPPORT.

**MANIFESTED IN-BAY SECONDARY PAYLOADS AS OF 10/1/88**

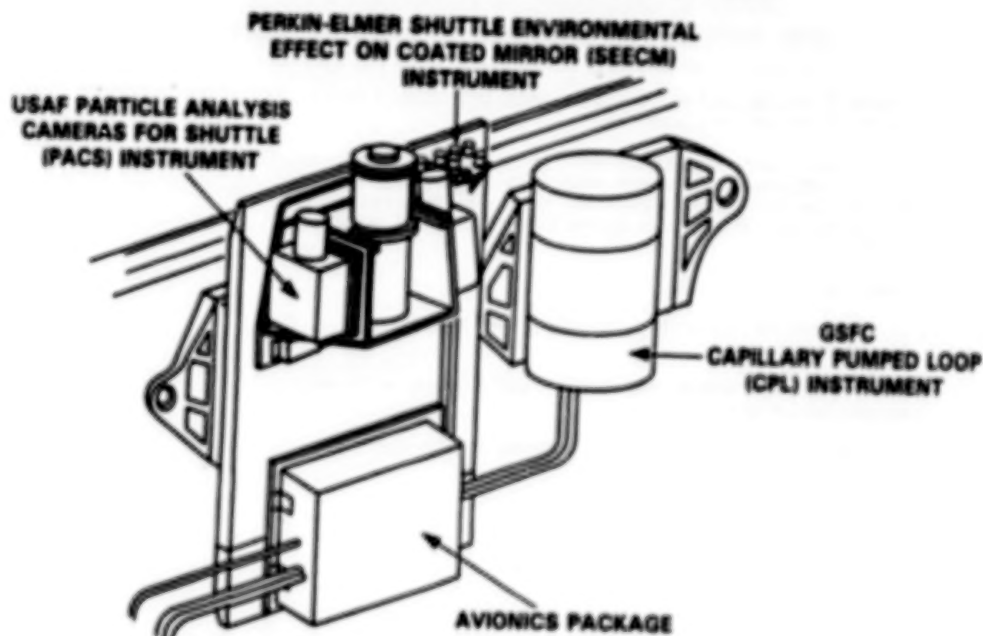
FLIGHT	PAYLOAD	ORG	WEIGHT	CARRIER
89- 2/18	SHARE	CDR	830	UNIQUE
89- 2/18	SSBUV-1	CDE	1219	* CSCP
90-11/08	SSBUV-2	CDE	1219	* CSCP
90-TBD	TPC	CDR	495	* CSCP
91- 1/31	PMG-1	CDM	730	* HH-G
91- 1/31	ASP	CDX	840	* HH-G
91- 8/15	FTS-DTF-1	CDB	1500	TBD
91-12/23	CDX-1	CDC	4000	* HH-M
92- 2/27	DEE	CDM	300	UNIQUE
92- 2/27	SDS-1	CDE	930	* HH-G
92- 6/11	ECOM/TEMP2AJ	CDB	2345	UNIQUE
92- 6/11	SSBUV-3	CDE	1219	* CSCP
92- 7/30	CTM	CDR	830	* HH-G
92- 7/30	HPE	CDR	930	* HH-G
92-10/29	SPARTAN-2	CDE	5700	SPARTAN
92-11/19	SEDS	CDM	350	UNIQUE
92-TBD	CGAS-1	CDC	500	* CSCP
93- 1/14	MAST-1 CBI	CDM	7000	UNIQUE
93- 2/11	LTS-1	CDR	4900	UNIQUE
93- 2/11	CDX-2	CDC	3600	* HH-M
93- 3/18	SDS-2	CDE	740	* HH-G
93- 4/04	SPH	CDM	3200	* HH-M
93- 4/15	MEL-3	CDE	5700	MEL
93- 6/10	SSBUV-4	CDE	980	* CSCP
93- 6/17	FTS-DTF-2	CDB	5500	TBD
93- 6/17	CDX-1	CDC	8000	MEL
93- 8/05	CDX-3	CDC	3800	* HH-M
93- 8/20	SRAD	CDB	5700	UNIQUE
93-12/7	CGAS-2	CDC	500	* CSCP
93-TBD	CGAS-3	CDC	500	* CSCP

\* HITCHHIKER / CSCP PAYLOADS

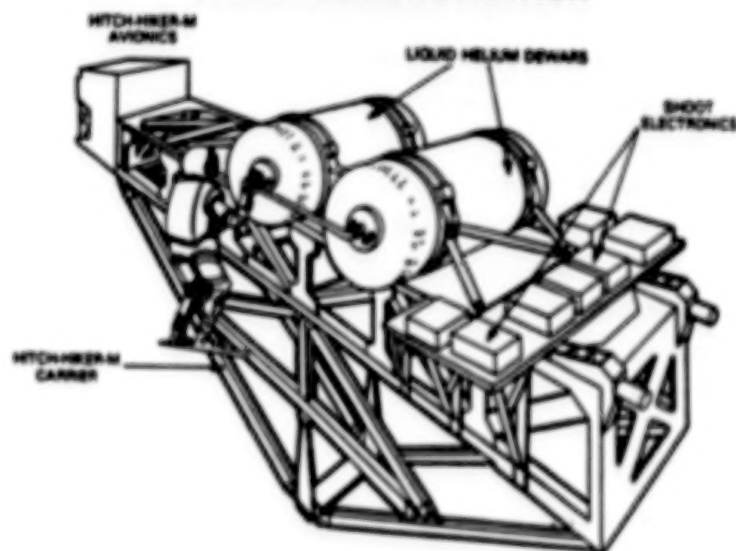
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**HITCHHIKER-G MISSION ONE**



**SUPERFLUID HELIUM ON ORBIT TRANSFER  
FLIGHT DEMONSTRATION**



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**Space Shuttle System Payload Integration Process**  
***Hitchhiker Project Overview***

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**SPOC FEATURES FOR REDUCTION OF CUSTOMER COSTS**

- STANDARD PRE-DEFINED INTERFACES REDUCE ENGINEERING EFFORT, DESIGN ITERATION, AND LEAD TIME.
- TRANSPARENT DATA SYSTEM ALLOWS USE OF CUSTOMER'S OWN GROUND SUPPORT EQUIPMENT, SOFTWARE, AND PERSONNEL DURING PAYLOAD INTEGRATION AND FLIGHT OPERATIONS MINIMIZING RETRAINING AND RETESTING EFFORTS AND ALLOWING THE CUSTOMER MAXIMUM AUTONOMY.
- SIMPLE MOUNTING SCHEME.
- CANISTER OPTION PROVIDES CONTAINMENT AND REDUCES SAFETY ANALYSIS.
- SHORT HANDS-ON INTEGRATION PERIOD - INSTRUMENTS DELIVERED AS LATE AS 1-3 MONTHS.
- REDUCED REQUIREMENTS FOR CONFERENCES, TRAVEL, ETC.

**TYPICAL HITCHHIKER SCHEDULE MILESTONES (MONTHS)**

CUSTOMER SUBMITS CUSTOMER PAYLOAD REQUIREMENTS DOCUMENT	-24
CUSTOMER PAYLOAD ACCOMMODATION CONFERENCE AT GSFC	-23
PRELIMINARY SAFETY DATA	-18
CUSTOMER PAYLOAD DELIVERED TO GSFC	-4
INTEGRATED PAYLOAD DELIVERED TO LAUNCH SITE	-3
LAUNCH	0
CUSTOMER PAYLOAD RETURNED TO CUSTOMER	1
ALL DATA DELIVERED TO CUSTOMER	1

PRELIMINARY



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**HITCHHIKER MECHANICAL ACCOMMODATIONS**

• **PLATE**

- THE LARGE PLATE IS 50 X 50 INCHES AND CAN ACCOMMODATE UP TO 250 LBS OF CUSTOMER HARDWARE IN ADDITION TO THE SPOC AVIONICS.
- THE SMALL PLATE IS 25 X 25 INCHES AND CAN ACCOMMODATE 100 LBS.
- PLATES HAVE A GRID OF 3/8 BOLT HOLES ON 70 MM CENTERS.

• **CANISTER**

- THE CANISTERS CAN ACCOMMODATE A PAYLOAD 19.25 INCHES (5M) X 26 INCHES (HEIGHT).
- CANISTERS WITH OPENING DOORS CAN ACCOMMODATE 170 LB PAYLOADS.
- SEALED CANISTERS (1 ATM AIR OR NITROGEN) CAN ACCOMMODATE 200 LB.

• **BRIDGE (H-H)**

- THE BRIDGE HAS THREE ATTACHMENT LOCATIONS EACH ON THE TOP, FRONT, AND REAR OF THE TRUSS. THE TOP LOCATIONS CAN ACCOMMODATE UP TO 300 LBS EACH AND THE SIDE LOCATIONS CAN ACCOMMODATE UP TO AT LEAST 170 LBS. THE SIDE MOUNTING AREAS ARE 27 X 26 INCHES AND THE TOP MOUNTS ARE 26 X 26 INCHES. STANDARD MOUNTING HOLES ARE PROVIDED.

• **THERMAL**

- THERMAL CONTROL SURFACES, HEATERS, THERMOSTATS, ETC. ON PLATE MOUNTED CUSTOMER EQUIPMENT ARE PROVIDED BY THE CUSTOMER.
- GSFC PROVIDES EXTERNAL THERMAL BLANKET OR WHITE PAINT SURFACE FOR CANISTERS.
- NO FLUID LOOP COOLING IS PROVIDED BUT SEVERAL HUNDRED WATTS (CONTINUOUS) OR SEVERAL KW (SHORT PERIODS) OF HEAT DISSIPATION CAN USUALLY BE ACCOMMODATED BY RADIATION AND TEMPORARY STORAGE OF HEAT IN THE THERMAL MASS OF THE EQUIPMENT.

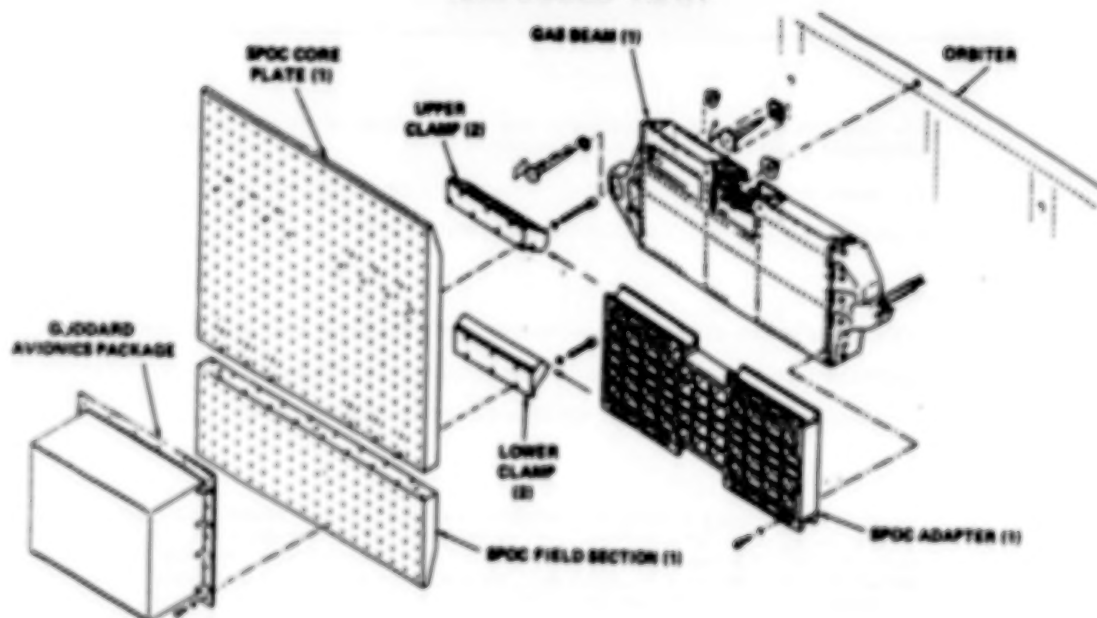
• **ATTITUDE CONTROL**

- ORBITER CAN POINT AT A TARGET WITHIN 9 ARC MINUTES (5 ARC MIN FOR SHORT PERIODS).
- USER SUPPLIED POINTING SYSTEM CAN BE USED TO IMPROVE POINTING ACCURACY.
- NOMINAL SHUTTLE ATTITUDE IS BAY DOWN.

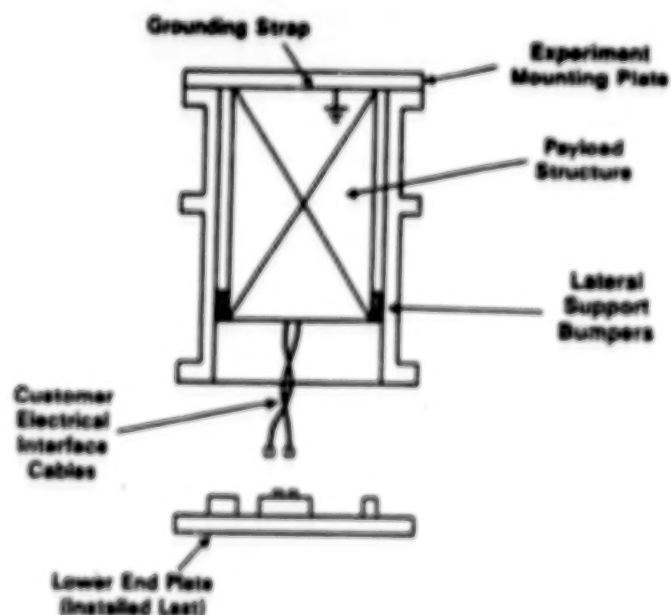
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**SPOC STRUCTURAL ASSEMBLY  
 (EXPLODED VIEW)**



**Hitchhiker-G Canister**  
 Mechanical and Electrical Interfaces



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**Space Shuttle System Payload Integration Process**  
**Hitchhiker Project Overview**

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**CUSTOMER ELECTRICAL INTERFACES**

The standard electrical interface or "port", consists of a signal cable and a separate power cable which provide the following:

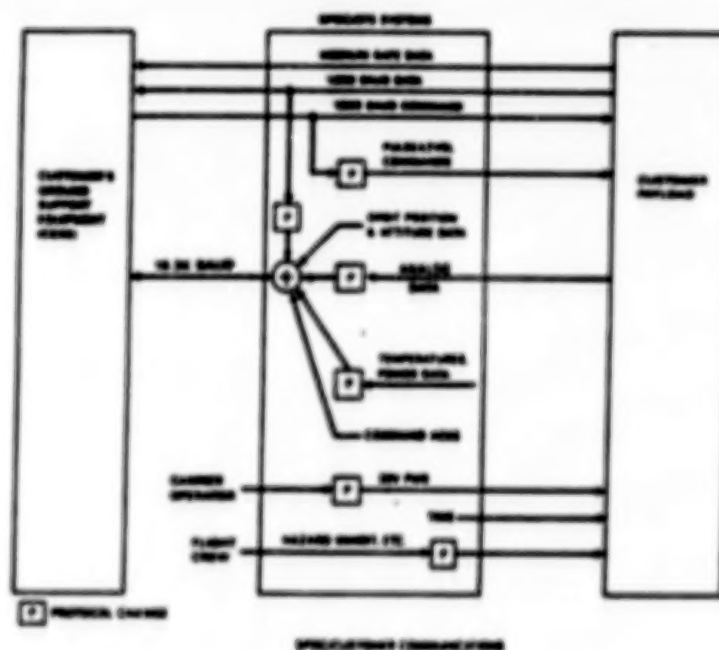
- Two 38 V (+/- 4 V) 10 Amp. power lines which can be turned on (together) by ground command. Customer power and energy are monitored by the carrier system. The maximum simultaneous total customer power for a Hitchhiker is 1200 W and the nominal maximum total customer energy is 8 KWH/day with additional energy available. Non-Hitchhiker payloads may use up to 1650 W (1200 W for 15 minutes) and 10 KWH/day.
- Four 28V bi-level or pulse commands (10 ms max) which can be used with relay drivers and relays to control additional power switching within a payload. (For customer payloads one command is reserved for control of the door.)
- An asynchronous 1200 baud uplink command channel.
- An asynchronous 1200 baud low-rate downlink data channel. This data is available over Ku-band service or S-band service and can also be recorded on the orbiter's tape recorder.
- A medium-rate downlink channel (1-1400 KB/s) for use with the real-time-only Ku-band TDRS service. The total simultaneous customer data rate for the carrier cannot exceed 1400 KB/s.
- IRIG-B serial time code and a one pulse per minute square wave signal which can be supplemented by a time command via the above asynchronous uplink channel.
- Three channels for temperature sensors to allow measurement of payload temperatures even when the payload power is off (for customer payloads these channels are reserved for door position, canister pressure, and temperature).
- An analog channel, 0-5V, 8 bit quantizing, 10 hertz sample rate. An index pulse is also supplied which can be used to advance a user supplied analog multiplexer to allow measuring a large number of parameters.

**SPOC TRANSPARENT DATA SYSTEM COMMUNICATIONS**



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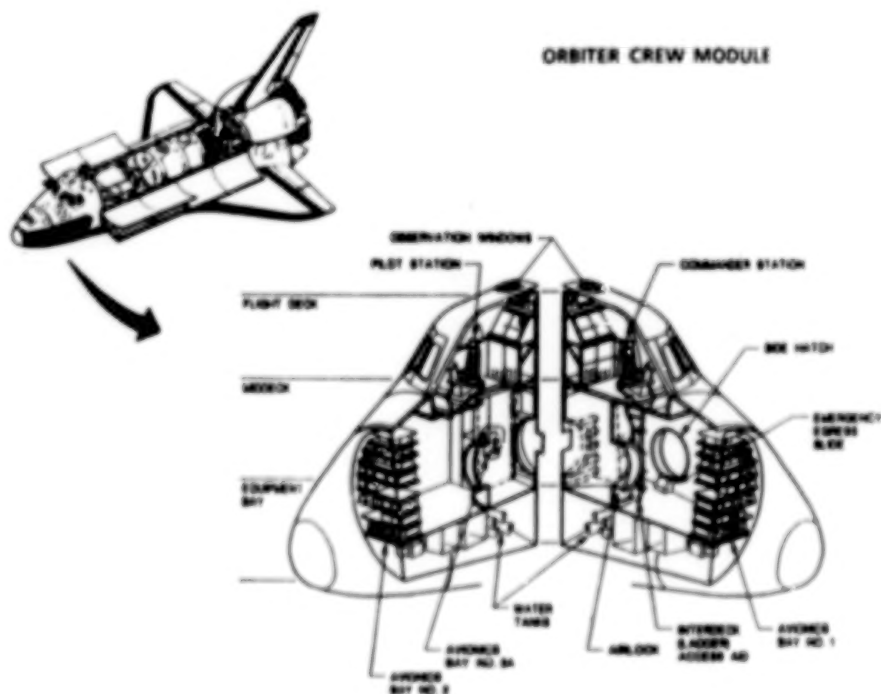


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Space Shuttle System Payload Integration Process  
***Middeck Payload Integration: Orbiter Crew Module Description***

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Johnson Space Center, Spacelab Middeck Integration Office

MIDDECK PAYLOAD INTEGRATION

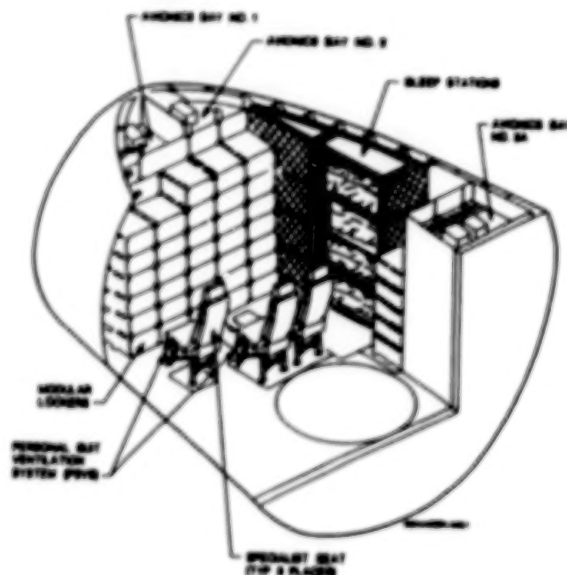
- ORBITER CREW MODULE DESCRIPTION
- MIDDECK PAYLOAD ACCOMMODATIONS
- PAYLOAD DESIGN GUIDELINES/CONSIDERATIONS
- SCHEDULES/MANIFESTING



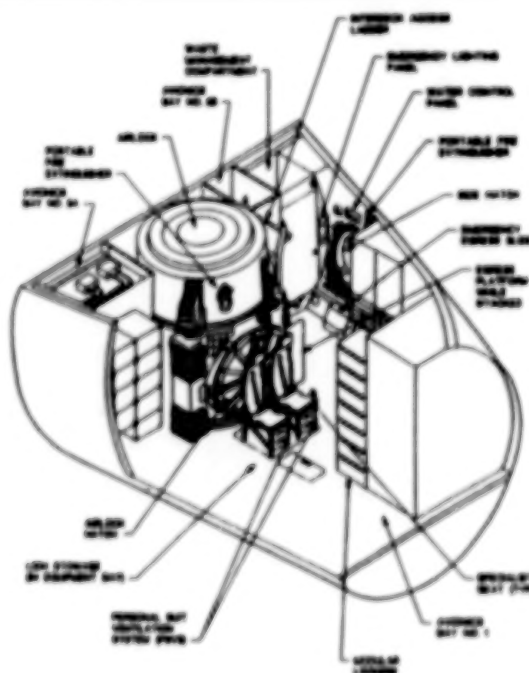


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*Middeck Payload Integration: Orbiter Crew Module Description*

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MIDDECK - RIGHT SIDE VIEW LOOKING FORWARD AND OUTBOARD



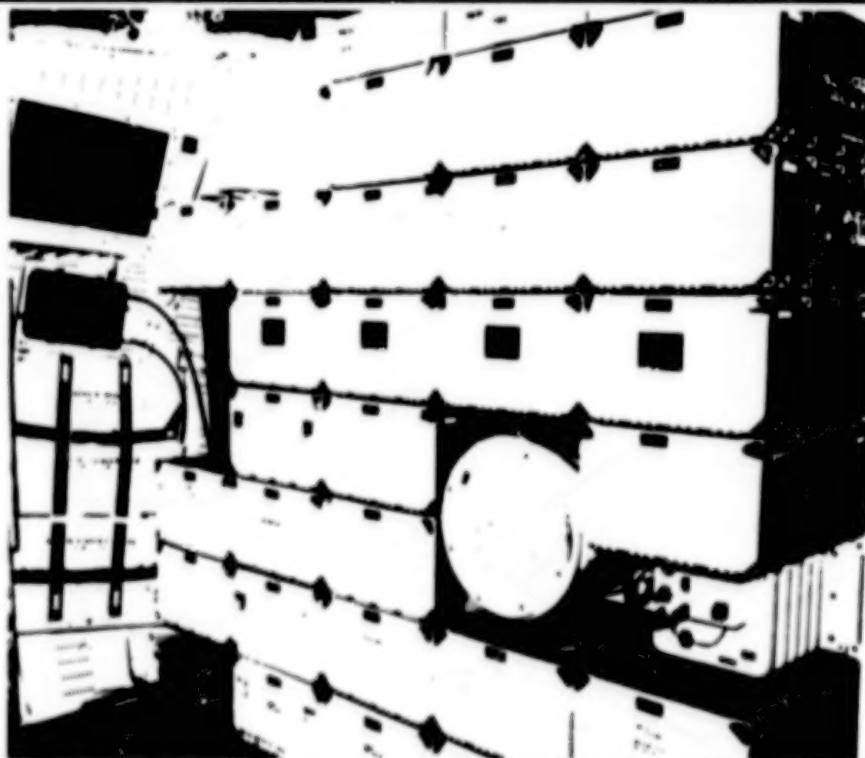
MIDDECK - LEFT SIDE VIEW LOOKING AFT AND OUTBOARD

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Space Shuttle System Payload Integration Process  
*Middeck Payload Integration: Middeck Payload Accommodations*

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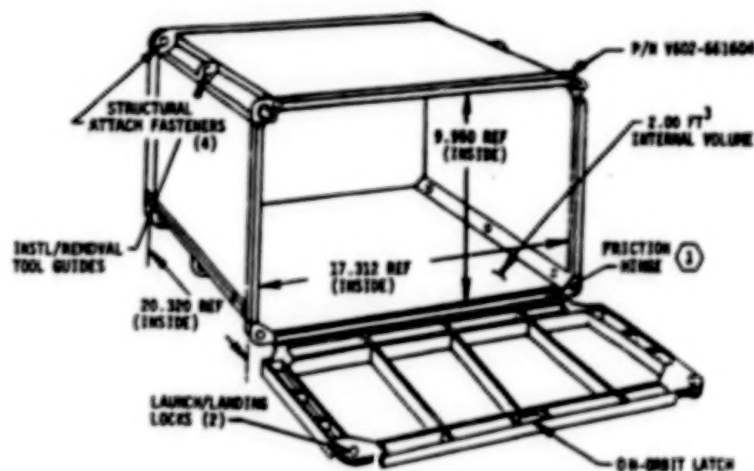
PHYSICAL ACCOMMODATIONS

- LOCKER STOWED PAYLOAD
  - 54 POUND MAX PAYLOAD WEIGHT
  - CENTER-OF-GRAVITY (CG) OF LOCKER CAN BE NO MORE THAN 14 INCHES FROM FACE OF ORBITER WIRE TRAY
  - LOCKER PROVIDES 2 CUBIC FEET OF STORAGE VOLUME
- NONLOCKER PAYLOAD
  - 69 POUND MAX PAYLOAD WEIGHT - ONE LOCKER REPLACEMENT
  - 120 POUND MAX PAYLOAD WEIGHT - TWO LOCKER REPLACEMENT
  - CG OF PAYLOAD CAN BE NO MORE THAN 14 INCHES FROM FACE OF ORBITER WIRE TRAY
  - MAX PAYLOAD WEIGHT CG DEPENDENT
  - PAYLOAD SHALL NOT PROTRUDE BEYOND FACE OF LOCKERS



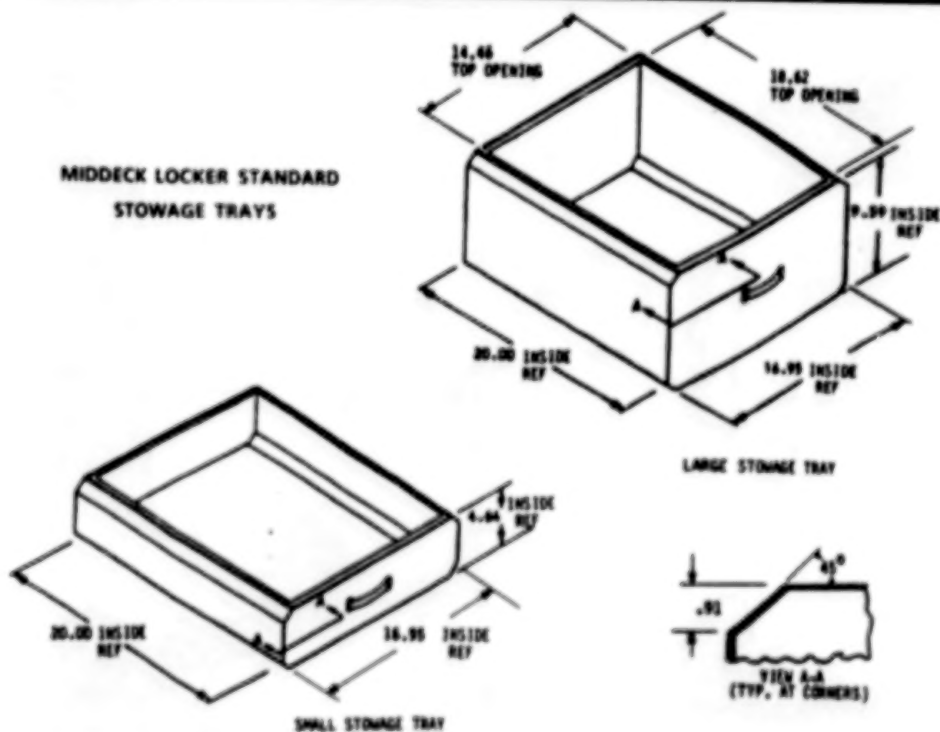
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Space Shuttle System Payload Integration Process  
*Middeck Payload Integration: Middeck Payload Accommodations*

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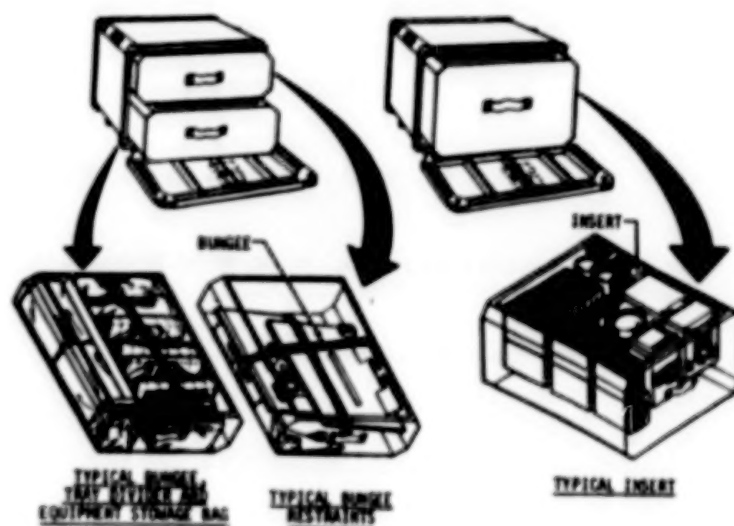
STANDARD MIDDECK MODULAR LOCKER

**MIDDECK LOCKER STANDARD  
STOWAGE TRAYS**

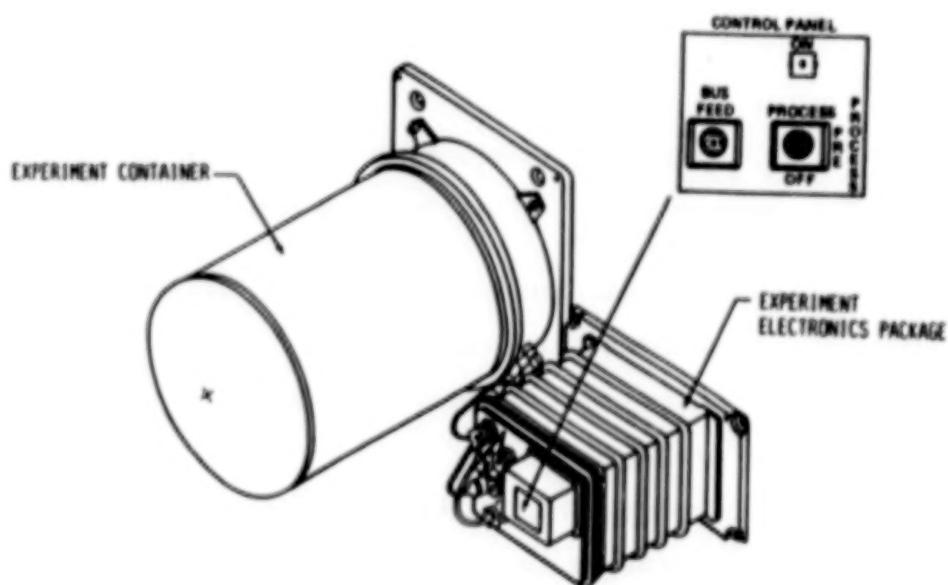


**HUMANS IN SPACE**  
Space Shuttle System Payload Integration Process  
*Middeck Payload Integration: Middeck Payload Accommodations*

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Johnson Space Center, Spacelab Middeck Integration Office



MIDDECK MODULAR STORAGE LOCKER CONFIGURATIONS



EXAMPLE NONLOCKER MIDDECK PAYLOAD

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ELECTRICAL POWER

- NOMINAL 28 VOLT DC, LIMITED TO 115 WATTS MAX CONTINUOUS
- POWER GENERALLY NOT AVAILABLE DURING ASCENT/DESCENT
- STANDARD POWER CABLES PROVIDED BY NSTS

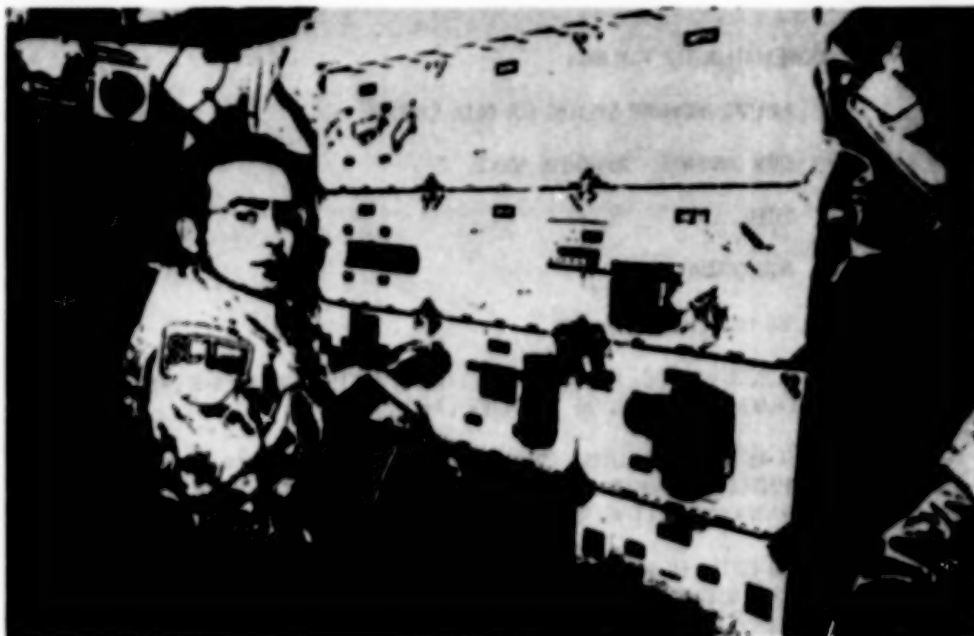
THERMAL

- COOLING
  - HEAT DISSIPATED INTO CREW COMPARTMENT BY PASSIVE OR FORCED AIR COOLING
  - PASSIVE AIR COOLING - HEAT LOAD LIMITED TO 60 WATTS MAX CONTINUOUS FOR LOCKER STORED PAYLOAD
  - FORCED AIR COOLING - HEAT LOAD LIMITED TO 115 WATTS MAX CONTINUOUS
    - PAYLOAD PROVIDES AIR CIRCULATION FAN
    - AIR OUTLET TEMPERATURE LIMITED TO 120°F MAX
- EXTERNAL SURFACE TEMPERATURES
  - PAYLOAD SURFACES ACCESSIBLE TO CREW LIMITED TO 113°F MAX
  - PAYLOAD SURFACES INACCESSIBLE TO CREW LIMITED TO 120°F MAX



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- PAYLOAD OPERATIONS LIMITED TO MIDDECK EXCEPT FOR "OUT-THE-WINDOW" PHOTOGRAPHIC ACTIVITIES
- NO PAYLOAD OPERATIONS ON LAUNCH AND LANDING DAYS EXCEPT FOR SIMPLE ACTIVATION/DEACTIVATION ACTIVITIES
- PAYLOAD OPERATIONS REQUIRING CREW INVOLVEMENT ALLOWED ONLY DURING CREW AWAKE PERIODS
- NORMAL SHUTTLE FLIGHT HAS ONE-SHIFT ON-ORBIT WORKDAY OF 10 HOURS WITH 8 HOURS AVAILABLE FOR PAYLOAD OPERATIONS. AN ADDITIONAL 1 HOUR MAY BE AVAILABLE JUST BEFORE AND JUST AFTER THE NORMAL WORKDAY FOR SIMPLE PAYLOAD OPERATIONS
- TYPICAL SHUTTLE FLIGHT HAS A CREW OF 5 AND A DURATION OF 4-5 DAYS
- NO GROUND COMMANDING OR DATA DOWNLINK AVAILABLE FOR MIDDECK PAYLOADS

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- DOCUMENTATION FOR PAYLOADS
  - PAYLOAD PROVIDED SYSTEMS FOR DATA STORAGE
  - CREW COMMENTS - AUDIO/LOG BOOKS
  - VIDEO
  - PHOTOGRAPHY
- PAYLOAD INSTALLATION/REMOVAL
  - MIDDECK PAYLOADS NORMALLY INSTALLED IN SHUTTLE ORBITER 3-8 DAYS PRIOR TO LAUNCH AND REMOVED ONE DAY AFTER LANDING
  - IF ABSOLUTELY REQUIRED (SUBJECT TO NSTS APPROVAL) INSTALLATION OF MIDDECK PAYLOADS MAY BE PROVIDED AS LATE AS 18 HOURS PRIOR TO LAUNCH AND REMOVAL AS EARLY AS 2 HOURS AFTER LANDING
- PAYLOAD INSTALLED ORIENTATION SHOULD BE CONSIDERED DURING DESIGN - WILL BE DIFFERENT DURING LAUNCH AND LANDING PHASES
- SHUTTLE DOES NOT PROVIDE ABSOLUTE ZERO-GRAVITY ENVIRONMENT - CREW MOVEMENTS, CREW TREADMILL EXERCISE, THRUSTER FIRINGS, AND OTHER PAYLOAD OPERATIONS WILL INDUCE DISTURBANCES
- MATERIALS SELECTION VERY IMPORTANT FOR MIDDECK PAYLOADS TO PROTECT THE CREW AND ORBITER
  - TOXICITY
  - FLAMMABILITY
  - NUCLEAR RADIATION
- WORKING IN LOW GRAVITY GENERALLY REQUIRES MORE TIME THAN SAME TASK ON GROUND
- IF PAYLOAD ASSEMBLY IS REQUIRED ON-ORBIT, AVOID USE OF SMALL PARTS THAT CAN GET LOOSE IN CABIN
- VELCRO (NSTS APPROVED TYPE) CAN BE USED TO RESTRAIN PAYLOAD COMPONENTS DURING ON-ORBIT ACTIVITIES
- REDUNDANT/SPARE PARTS SHOULD BE CONSIDERED FOR CRITICAL PAYLOAD COMPONENTS
- SIMPLE IN-FLIGHT MAINTENANCE CAN BE DESIGNED INTO PAYLOAD, BUT MUST NOT VIOLATE SAFETY REQUIREMENTS AND MUST BE APPROVED BY NSTS

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Space Shuttle System Payload Integration Process  
*Middeck Payload Integration: Schedules/Manifesting*

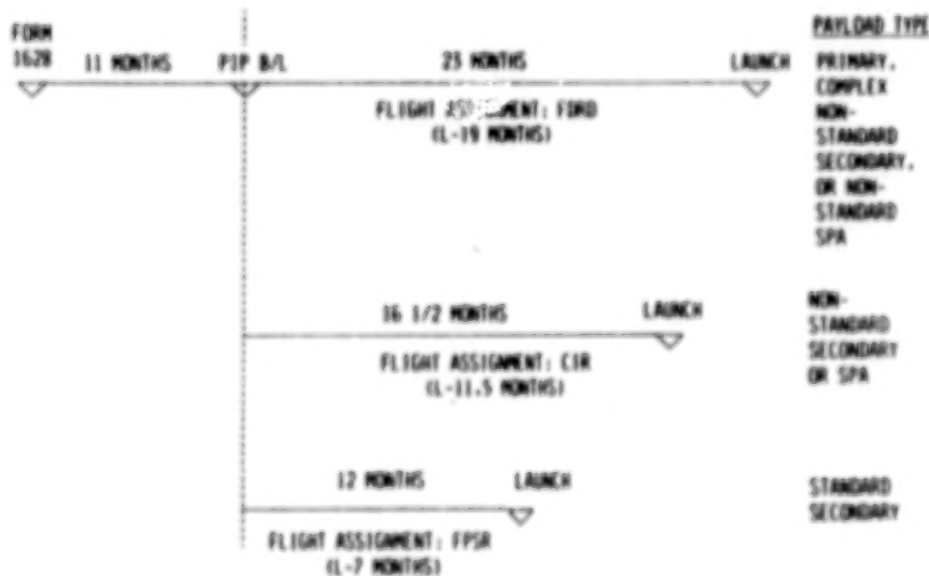
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**FLIGHT ASSIGNMENT**

PAYLOAD CATEGORY	LATEST FLIGHT ASSIGNMENT	PREREQUISITES
PRIMARY	FDRD L-19 MONTHS	BASELINED* PIP AND ICD
COMPLEX SECONDARY	FDRD L-19 MONTHS	BASELINED PIP AND ICD
NONSTANDARD SECONDARY OR SPA	CARGO INTEGRATION REVIEW (CIR) L-11.5 MONTHS	BASELINED PIP AND ICD. ALL ANNEXES BASELINED EXCEPT 4 AND 9; HOWEVER, CUSTOMER SUBMITTAL OF ANNEXES 4 AND 9 IS REQUIRED.
STANDARD SECONDARY	FLIGHT PLANNING AND STOWAGE REVIEW (FPSR) L-7 MONTHS	BASELINED PIP, ICD, AND ALL ANNEXES. PHASE II SAFETY REVIEW IS REQUIRED.

\*BASELINED = SIGNED BY BOTH NSTS AND THE CUSTOMER

**TIMELINE REQUIRED FOR FLIGHT READINESS**



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**KSC Payload Integration**

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Kennedy Space Center, Payload Support Office



PAYLOAD MANAGEMENT RESPONSIBILITIES

● KENNEDY SPACE CENTER (KSC) IS THE PRIMARY NASA LAUNCH SITE

- RESPONSIBLE FOR THE MANAGEMENT AND DIRECTION OF:

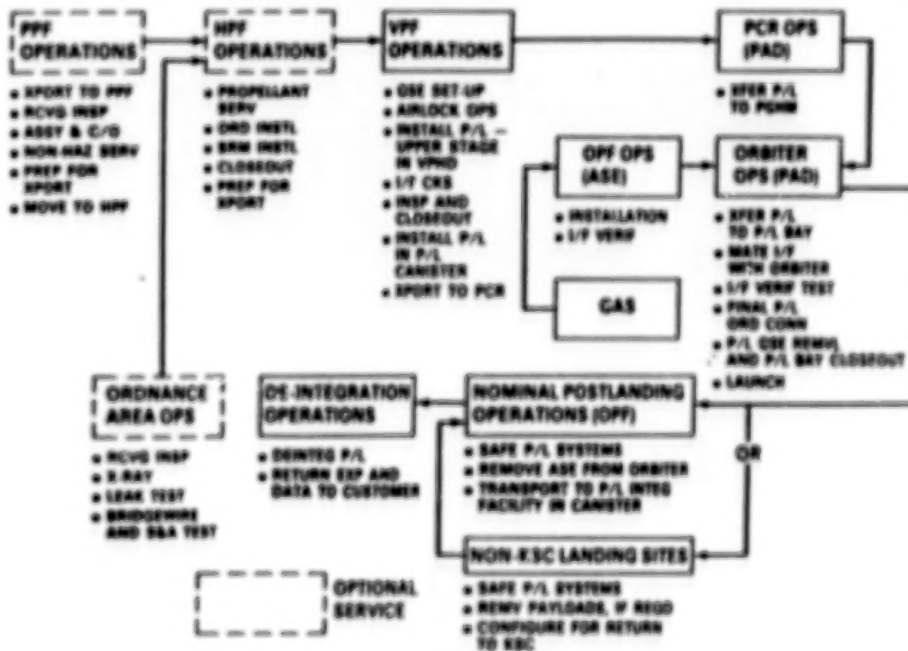
- ASSEMBLY AND VERIFICATION OF THE SHUTTLE
- ASSEMBLY AND PROCESSING OF SPACELAB AND SIMILAR TYPE PAYLOADS
- SUPPORT OF PAYLOAD PROCESSING AND FINAL PREPARATION FOR LAUNCH
- FINAL TEST AND INTEGRATION OF PAYLOADS IN THE ORBITER BAY BEFORE LAUNCH
- FINAL TEST AND INTEGRATION OF PAYLOADS WITH EXPENDABLE VEHICLES
- COUNTDOWN AND LAUNCH
- FACILITIES, COMMUNICATIONS, AND DATA SUPPORT TO EARLY PHASE OF ORBITAL ACTIVITY WHEN REQUIRED
- PRIMARY AND CONTINGENCY LANDING SITE OPERATIONS
- DEINTEGRATION OF PAYLOADS FROM THE STS UPON THEIR RETURN FROM SPACE
- PERFORMING THE HOST ROLE AS THE CUSTOMER'S AGENT

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EXAMPLE OF PAYLOAD FLOW FOR O&C INTEGRATION



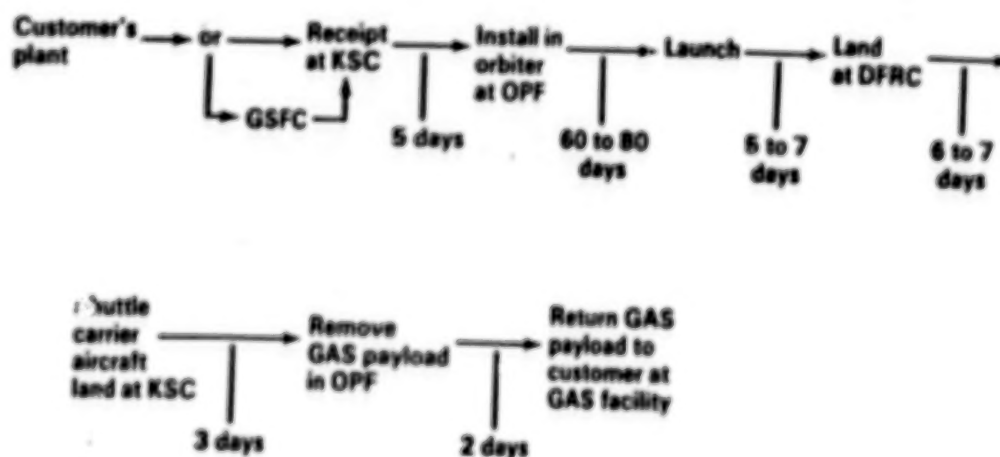
EXAMPLE OF PAYLOAD FLOW FOR VPF INTEGRATION



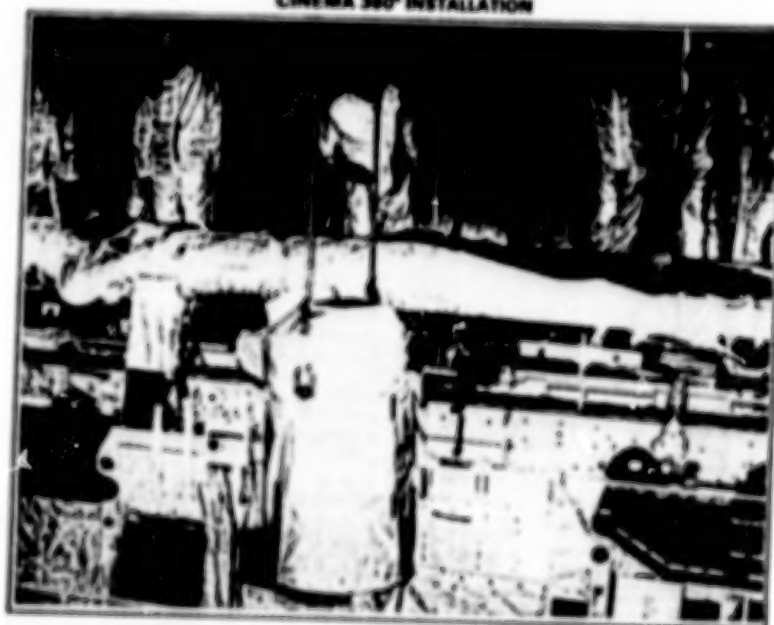
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**KSC  
 GET-AWAY SPECIAL  
 PAYLOAD PROCESSING**



CINEMA 360° INSTALLATION



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**GENERIC EXPERIMENT PHYSICAL AND FUNCTIONAL FAMILIARIZATION**

---

- ① PERSONNEL ASSIGNED AFTER THE PAYLOAD EXPERIMENT COMPLEMENT IS DEFINED
  - ASSIGNMENT CONTINUES THROUGH EXPERIMENT DEINTEGRATION
  
- ① PERSONNEL PARTICIPATE IN
  - EXPERIMENT AND PAYLOAD DESIGN REVIEWS AT DESIGN FACILITY
  - TECHNICAL EXCHANGE MEETINGS
  - PAYLOAD GROUND OPERATIONS WORKING GROUP MEETINGS AT KSC
  - INTEGRATION AND TESTING ACTIVITIES AT THE EXPERIMENT DEVELOPER'S FACILITY
  
- ① PERSONNEL UTILIZE KNOWLEDGE ABOUT EXPERIMENTS TO
  - DEVELOP INPUTS FOR KSC PROCESSING SCHEDULES
  - DEVELOP PROCEDURES FOR EXPERIMENT ACTIVITIES AT KSC
  - EVALUATE REQUIREMENT VALIDITY AND IMPACT

**GENERIC EXPERIMENT PRE-TURNOVER SUPPORT**

---

- ① EVALUATE PRE-TURNOVER ACTIVITIES AND PROVIDE TASK DIRECTION FOR HAZARDOUS OPERATIONS
  
- ① PARTICIPATE IN POST DELIVERY TESTS CONDUCTED BY EXPERIMENT DEVELOPER
  - KSC ENGINEERS GAIN ADDITIONAL EXPERIENCE WITH EXPERIMENT
  - KSC ENGINEERS KEEP AHEAD OF EXPERIMENT STATUS
  
- ① PROVIDE GENERIC TEST EQUIPMENT AND FACILITIES
  
- ① PROVIDE SERVICING SUPPORT AS REQUIRED

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**KSC Payload Integration**

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**EXPERIMENT INTEGRATION**

**INTRODUCTION**

- KSC PERFORMS EXPERIMENT INTEGRATION AS DEFINED BY THE PAYLOAD MISSION MANAGER REQUIREMENTS
- THE EXPERIMENTER IS AN INTEGRAL PART OF THE EXPERIMENT INTEGRATION TEAM
  - SETS UP AND VERIFIES EXPERIMENT GROUND SUPPORT EQUIPMENT
  - MONITORS AND OPERATES GSE DURING TESTING
  - PROVIDES DETAILS ON HOW EXPERIMENTS ARE OPERATED
  - PROVIDES EXPERIMENT EXPERTISE FOR PROBLEM RESOLUTION/UNIQUE EXPERIMENT OPERATIONS
  - INPUTS TO REVIEWS/SIGN-OFF PROCEDURES
- INTERFACE VERIFICATION POLICY
  - INTERFACES ARE VERIFIED AT EARLIEST OPPORTUNITY BY FUNCTIONAL TEST(S)
  - EXPERIMENT COMPATIBILITY IS VERIFIED USING MDT/MAJOR INTEGRATED TESTING
  - NO "FAILURE" MODE/UNIQUE SOFTWARE VALIDATION (EXCEPT SAFETY RELATED)

**EXPERIMENT INTEGRATION**

**REQUIREMENTS**

- PAYLOAD MISSION MANAGER PROVIDES REQUIREMENTS DOCUMENT WITH ALL KSC PROCESSING REQUIREMENTS TO LSSM INCLUDING:
  - OFF-LINE FACILITY SUPPORT
  - EXPERIMENT INSTALLATION
  - INTERFACE VERIFICATION
  - SERVICING, ALIGNMENT, AND CALIBRATION
  - LAUNCH DELAY CONTINGENCIES
  - DEINTEGRATION
  - EXPERIMENTER POST FLIGHT SUPPORT
  - CONTINGENCY LANDING SITE PROCESSING
- KSC RESPONDS TO REQUIREMENTS WITH THE KSC LAUNCH SITE SUPPORT PLAN (LSSP), ANNEX B OF THE PAYLOAD INTEGRATION PLAN (PIP)
- LSSP COMMITS KSC RESOURCES:
  - IDENTIFIES INTEGRATION PHASE OF REQUIREMENT
  - IDENTIFIES THOSE REQUIREMENTS WHICH ARE NON-STANDARD (OPTIONAL SERVICES)
  - IDENTIFIES REQUIREMENTS WHICH CANNOT BE MET OR NEED FURTHER RESOLUTION (PRELIMINARY ONLY)

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**Space Shuttle System Payload Integration Process**  
***KSC Payload Integration***

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**EXPERIMENT INTEGRATION**

---

**PWM/PI/ED PARTICIPATION**

- o WORKS WITH KSC TO SATISFACTORILY IMPLEMENT REQUIREMENTS
- o PROVIDES PROCEDURE INPUTS RELATIVE TO PROPER EXPERIMENT OPERATION TO ENSURE ACCURATE TESTING AND HEALTH, REVIEW/SIGN RESULTANT PROCEDURES
- o PERFORM EXPERIMENT UNIQUE FUNCTIONS WHICH REQUIRE SPECIAL EXPERTISE OR TRAINING
- o CHECKOUT GSE IN USER ROOM
- o OPERATE GSE DURING KSC OPERATIONS (PASSIVE ACTIVITY)
- o PROVIDE EXPERIMENT EXPERTISE WHEN PROBLEMS OCCUR
- o EVALUATE EXPERIMENT GSE DATA
- o EVALUATE TEST RESULTS TO ENSURE OBJECTIVES ARE MET

**EXPERIMENT INTEGRATION**

---

**OFF-LINE PREPARATIONS**

- o "OFF-LINE" REFERS TO THOSE FUNCTIONS WHICH OCCUR OUTSIDE THE NORMAL SERIAL FLOW OF PAYLOAD HARDWARE INTEGRATION
  - NORMALLY PERFORMED BY EXPERIMENTER PERSONNEL
  - NORMALLY PERFORMED IN OFF-LINE AREAS (LAB, ETC.)
  - KSC PERSONNEL ONLY INVOLVED TO PROVIDE SUPPORT OR CONTROL HAZARDOUS OPERATIONS
- o "ON-LINE" REFERS TO THOSE FUNCTIONS WHICH OCCUR AS A PART OF THE INTEGRATION FLOW AFTER EXPERIMENT TURNOVER
  - NORMALLY PERFORMED BY KSC
  - NORMALLY OCCURRING IN THE INTEGRATION STAND/ORBITER

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Kennedy Space Center, Payload Support Office

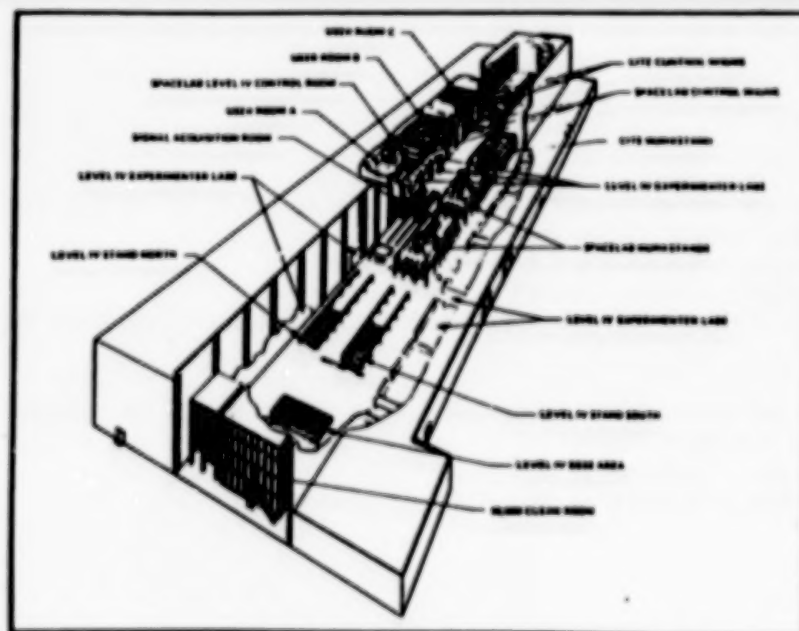
## EXPERIMENT INTEGRATION

### OFF-LINE ACTIVITIES

- THE PNM WILL PROVIDE KSC WITH A DATA PACKAGE DEFINING:

- (1) EXPERIMENT CONFIGURATION
- (2) OPEN WORK ITEMS (SCHEDULED)
- (3) NON-FLIGHT ITEMS (RED TAG)
- (4) OPEN PROBLEMS/VERIFICATIONS/NAIVERS
- (5) FLIGHT SPARES
- (6) BONDED STORAGE NEEDS
- (7) HAZARDS (LASERS, CRYOGENS, ETC.)

- THE PMA/PI/ED WILL CERTIFY THAT ALL GROUND SAFETY REVIEWS ARE COMPLETED (IDENTIFY ANY OPEN ITEMS) AND EXPERIMENT IS QUALIFIED FOR STS FLIGHT



### OBC BUILDING ASSEMBLY AND TEST AREA



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**GENERIC EXPERIMENT INTEGRATION WITH CARRIER**

- **MECHANICAL INTEGRATION ACTIVITIES, SUCH AS**
  - MISSION PECULIAR EQUIPMENT (HPE) INSTALLATION (E.G., FLUID LINES, CABLES, SUPPORT STRUCTURES)
  - EXPERIMENT INSTALLATION
  - HPE AND EXPERIMENT HARDWARE MODIFICATIONS
- **MECHANICAL MISSION DEPENDENT ACTIVITIES, SUCH AS**
  - EXPERIMENT ALIGNMENT
  - EXPERIMENT SERVICING
  - HPE FLUID SYSTEM LEAK CHECKS AND SERVICING
  - EXPERIMENT HARDWARE STORAGE (MODULE MISSIONS)
- **ELECTRICAL PRE-TEST ACTIVITIES, SUCH AS**
  - CONTINUITY AND MEGGER CHECKS
  - VOLTAGE AND POLARITY CHECKS
  - ISOLATION CHECKS

**GENERIC EXPERIMENT TESTING**

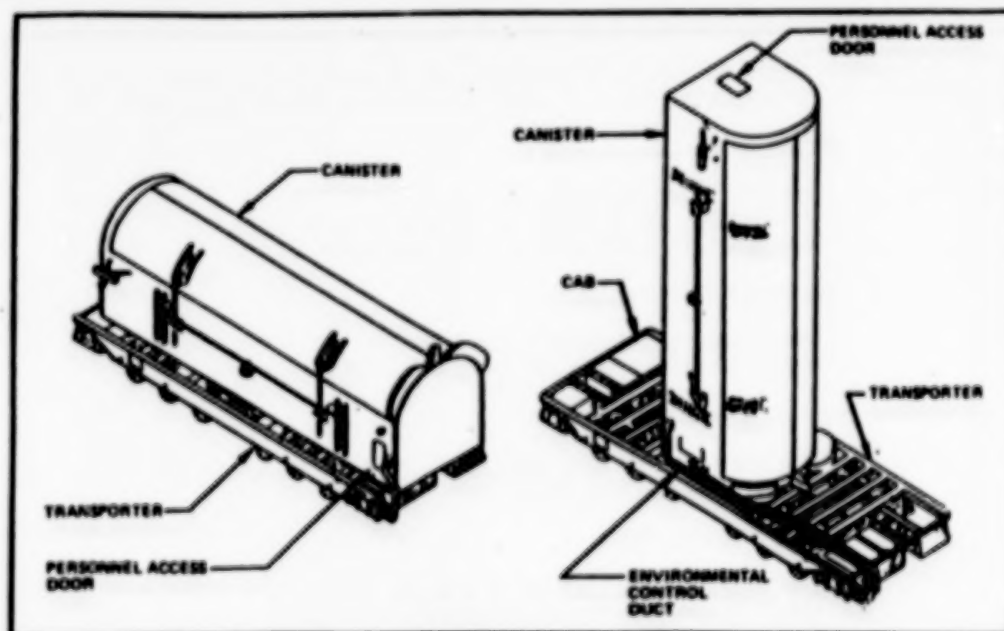
- **LEVEL IV EXPERIMENT FUNCTIONAL TESTS**
    - VERIFY EXPERIMENT TO SUBSYSTEM AND TO ORBITER INTERFACES
    - VERIFY EXPERIMENT FUNCTIONAL OPERATIONS TO EXTENT PRACTICAL
  - **INTEGRATED TESTS**
    - MOST SYSTEMS/EXPERIMENTS ARE ACTIVE
    - SYSTEMS/CREW ARE UTILIZED IN MAXIMUM RESOURCE MODE
    - COMPATIBILITY BETWEEN EXPERIMENTS/SUBSYSTEMS IS VERIFIED
  - **CREW EQUIPMENT INTERFACE TESTS**
    - VERIFY CREW/CREW EQUIPMENT COMPATIBILITY
    - VERIFY EXPERIMENT/CREW EQUIPMENT INTERFACES AND COMPATIBILITY
  - **CITE TESTS (MISSION DEPENDENT)**
    - UTILIZED FOR FIRST TIME CONFIGURATIONS
    - PROVIDE HIGH FIDELITY SIMULATION OF ORBITER
  - **ORBITER INTERFACE TESTS**
    - PERFORMED AT EITHER THE OPF OR THE PAD
    - VERIFY PAYLOAD TO ORBITER INTERFACES
- NOTE: EXTENSIVE INVOLVEMENT BY FLIGHT CREW MEMBERS DURING EXPERIMENT TESTING FOR CERTAIN PAYLOADS, SUCH AS SPACELABS.

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**GENERIC EXPERIMENT SERVICING AND CLOSEOUT**

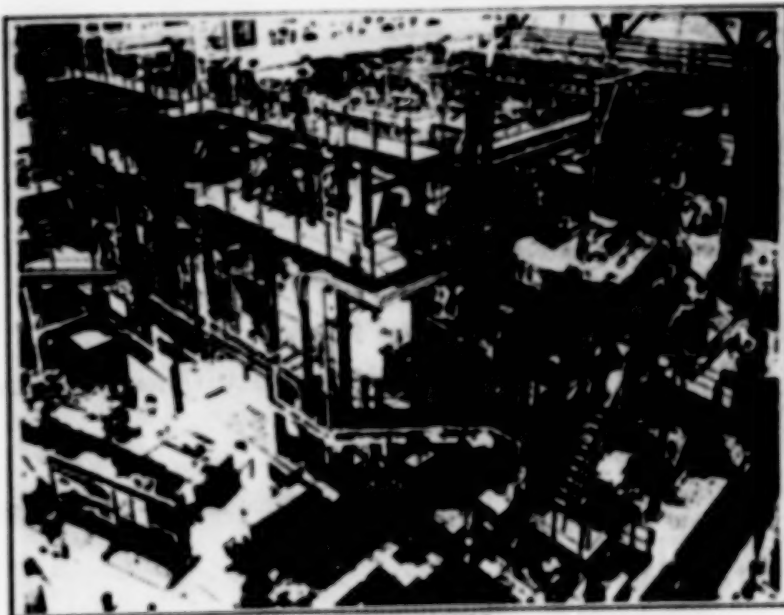
- 0 SERVICING AND CLOSEOUT OPERATIONS ARE MISSION DEPENDENT AND MAY BE PERFORMED IN THE OBC TEST STANDS, IN THE OPF, AND/OR AT THE PAD.
- 0 SERVICING AND PERIODIC MAINTENANCE, SUCH AS
  - EXPERIMENT PURGES
  - FLUIDS FILL/TOPPOFF
  - EXPERIMENT CALIBRATION
  - BATTERY INSTALLATION/CHARGE
- 0 CLOSEOUT ACTIVITIES, SUCH AS
  - PAYLOAD ENVELOPE CLEARANCE CHECKS
  - PAYLOAD WEIGHT AND CG MEASUREMENTS
  - PYROTECHNICS INSTALLATION AND VERIFICATION
  - EXPERIMENT UNIQUE OPERATIONS (E.G., REMOVE BEFORE FLIGHT ITEMS)
  - OPF TIME CONSTRAINED STORAGE AND CREW WALKDOWN (MODULE MISSIONS)
  - PAD LATE ACCESS FINAL STORAGE (E.G., BIOLOGICAL SAMPLES, SL-3 PRIMATES AND RODENTS)



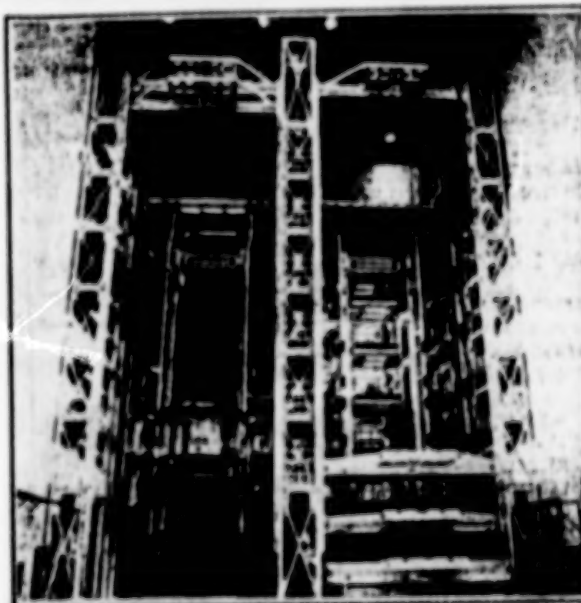
**CANISTER/TRANSPORTER CONFIGURATIONS**

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OFF WORKSTANDS



PAYLOAD AND UPPER STAGE INSTALLED IN A VPF WORK STAND

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**VERTICAL PROCESSING FACILITY ACTIVITIES**

- PAYLOAD INTEGRATION WITH ORBITER SYSTEMS AND OTHER PAYLOADS ALSO TAKES PLACE IN THE VERTICAL PROCESSING FACILITY (VPF)
- DELIVERY CONFIGURATION VARIES DEPENDING ON THE UPPER STAGE:
  - PAM ALREADY MATED WITH PAYLOAD
  - IUS/TDRS AND PAYLOAD ARRIVE SEPARATELY
  - SYNOCH CLASS AND ITS PGM ARRIVE SEPARATELY
- PAYLOAD ELEMENTS STACKING AND TESTS INVOLVE:
  - MATING WITH UPPER STAGE AS NECESSARY AND INSTALLATION INTO WORKSTAND IN PAYLOAD BAY SEQUENCE
  - STANDALONE HEALTH AND STATUS TESTS
  - INTEGRATION TESTS
    - ORBITER-TO-PAYLOAD INTERFACE VERIFICATION WITH PAYLOAD INTEGRATION TEST EQUIPMENT (CITE)
    - MISSION SEQUENCE TEST
    - END-TO-END TEST
    - ORDNANCE SYSTEMS TEST



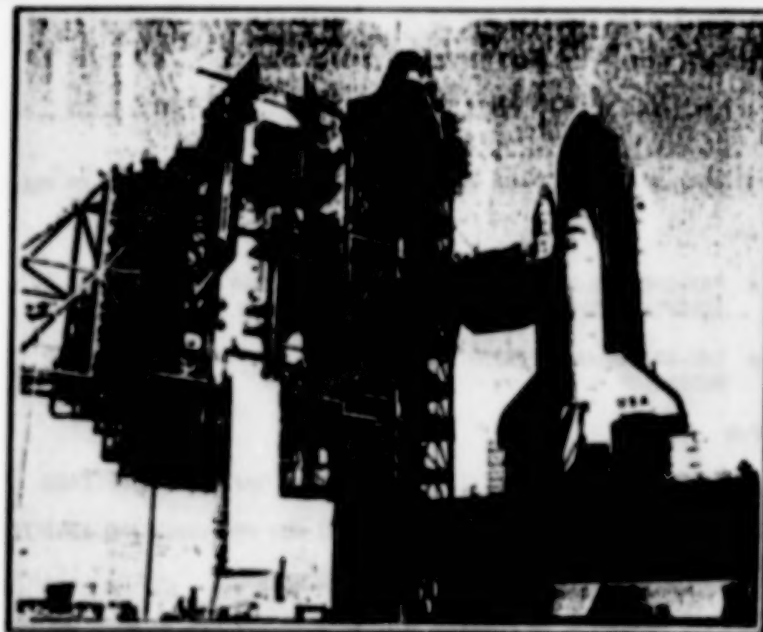
**CANISTER/TRANSPORTER BEING READY TO LEAVE VPF**

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CANISTER/TRANSPORTER ON PAD

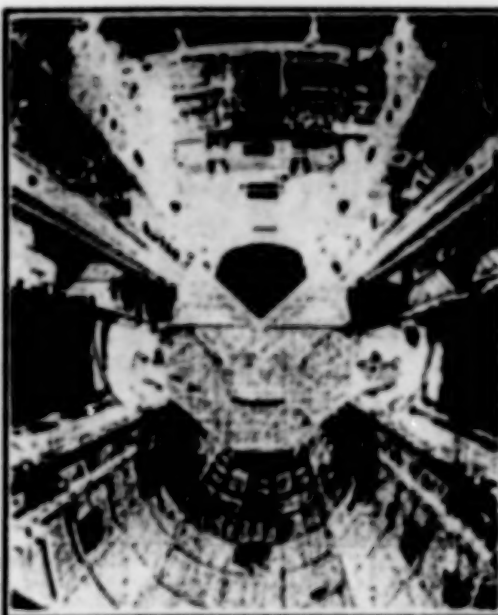


CANISTER BEING RAISED TO PCR



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PAYLOAD ELEMENTS BEING TRANSFERRED FROM THE PCR  
INTO THE SHUTTLE PAYLOAD BAY

ORIGINAL PAGE IS  
OF POOR QUALITY

**ORBITER INTEGRATION**

**0 AFTER PAYLOAD INSTALLATION IN ORBITER PAYLOAD BAY IN THE OPF OR THE PCR:**

**- OPF**

- PAYLOAD CABLES TO ORBITER ARE CONNECTED AND THE INTERFACE IS VERIFIED FROM FIRING ROOM AT LAUNCH CONTROL CENTER (LCC)
- END-TO-END AND MISSION SEQUENCE TESTS WILL BE PERFORMED (IF REQUIRED)

**- PCR**

- FINAL ORDNANCE CONNECTIONS ARE MADE AND SAFING IS COMPLETED
- ALL CLOSEOUT PREPARATIONS FOR FLIGHT ARE PERFORMED AND VERIFIED
- PAYLOAD BAY DOORS ARE CLOSED AT L-10 DAYS
- LATE SERVICING OR COMMANDS WILL BE ACCOMPLISHED THROUGH THE ORBITER UNBILICALS AS PART OF THE SHUTTLE COUNTDOWN PRIOR TO T-9 MINUTES
- ACCESS IS EXTREMELY LIMITED AFTER INSTALLATION OF THE PAYLOAD AT THE VPF AND PCR

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**PAYLOAD LAUNCH OPERATIONS CONTROL LOCATIONS**

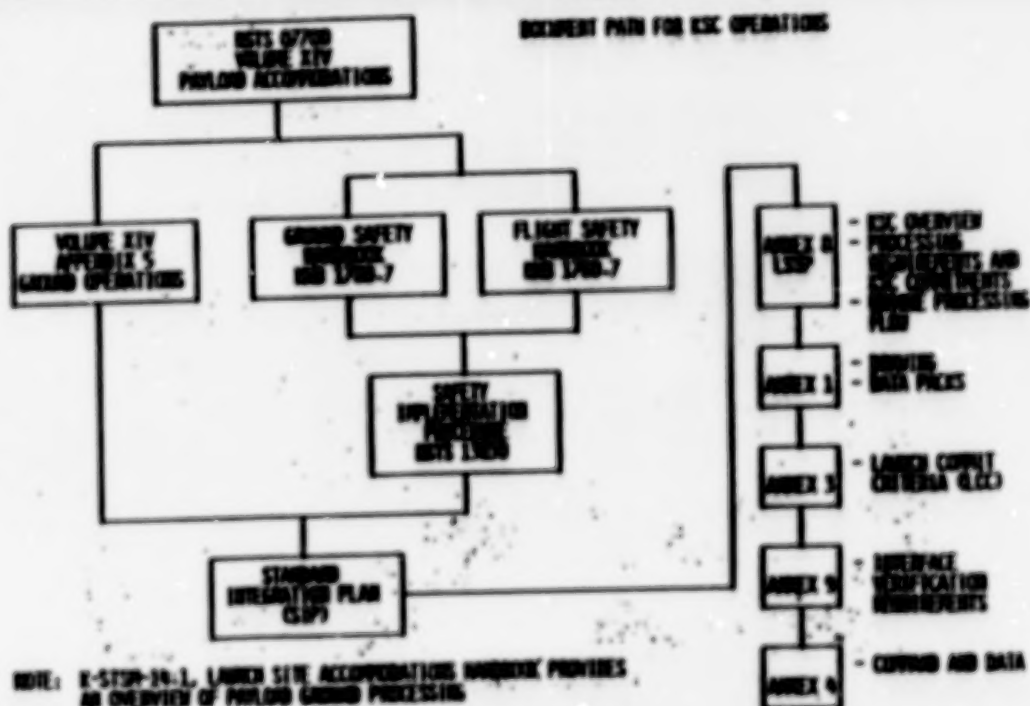
- **LAUNCH CONTROL CENTER (LCC)**
  - SHUTTLE COUNTDOWN AND LAUNCH CONTROL
  - KSC PAYLOAD MANAGEMENT AND TEST CONTROL
  - CUSTOMER ENGINEERING SUPPORT AREA (LPS DATA MONITORING)
- **MISSION DIRECTOR'S CENTER (VERTICAL PAYLOADS)**
  - CUSTOMER MANAGEMENT LAUNCH DIRECTION
  - COMMUNICATIONS TO ALL LOCATIONS
- **QMC CONTROL ROOM (HORIZONTAL PAYLOADS)**
  - CUSTOMER MANAGEMENT LAUNCH DIRECTION
  - COMMUNICATIONS TO ALL LOCATIONS
- **CUSTOMER'S KSC PAYLOAD CONTROL STATION (VERTICAL PAYLOADS)**
  - PAYLOAD COMMAND AND DATA EVALUATION
  - VOICE AND DATA COMMUNICATIONS TO LCC AND PAD
- **OFF-SITE CONTROL**
  - MISSION CONTROL AT JSC
  - PAYLOAD OPERATIONS CONTROL CENTER AT JSC
  - CUSTOMER'S MISSION CONTROL CENTER

**POSTLANDING OPERATIONS**

- **AFTER KSC OR DFRF LANDING AND CREW EGRESS:**
  - PAYLOAD BAY ENVIRONMENTAL LIMITS ARE MAINTAINED BY EXTERIOR UNITS
  - ORBITER IS TOWED TO A PROCESSING FACILITY FOR SAFING
  - REMOVAL OF RETURNING PAYLOADS AND AIRBORNE SUPPORT EQUIPMENT - APPROXIMATELY 3 DAYS AFTER LANDING AT KSC (EITHER DIRECT LANDING OR SHUTTLE CARRIER AIRCRAFT LANDING AT KSC)
  - PAYLOADS CAN BE TURNED OVER TO PAYLOAD OWNERS AS FOLLOWS:
    - SOME MIDDECKS CAN BE REMOVED PRIOR TO ORBITER TOW (LANDING + 2 HOURS)
    - REMAINING MIDDECK LOCKERS CAN BE REMOVED WITHIN 24 HOURS
    - OTHER PAYLOADS/ASE ARE REMOVED AFTER THE PAYLOAD BAY DOORS ARE OPENED (LAND AT KSC + 3 DAYS)
- **NON-KSC/DFRF LANDINGS ARE COVERED BY KYT-PL-0014 AND APPROPRIATE ANNEX, KSC OFF-SITE OPERATIONS PLAN AND KCS-PL-0012.0, PAYLOAD OPERATIONAL LOGISTICS PLAN**

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## **KENNEDY SPACE CENTER INTEGRATION ACTIVITIES**

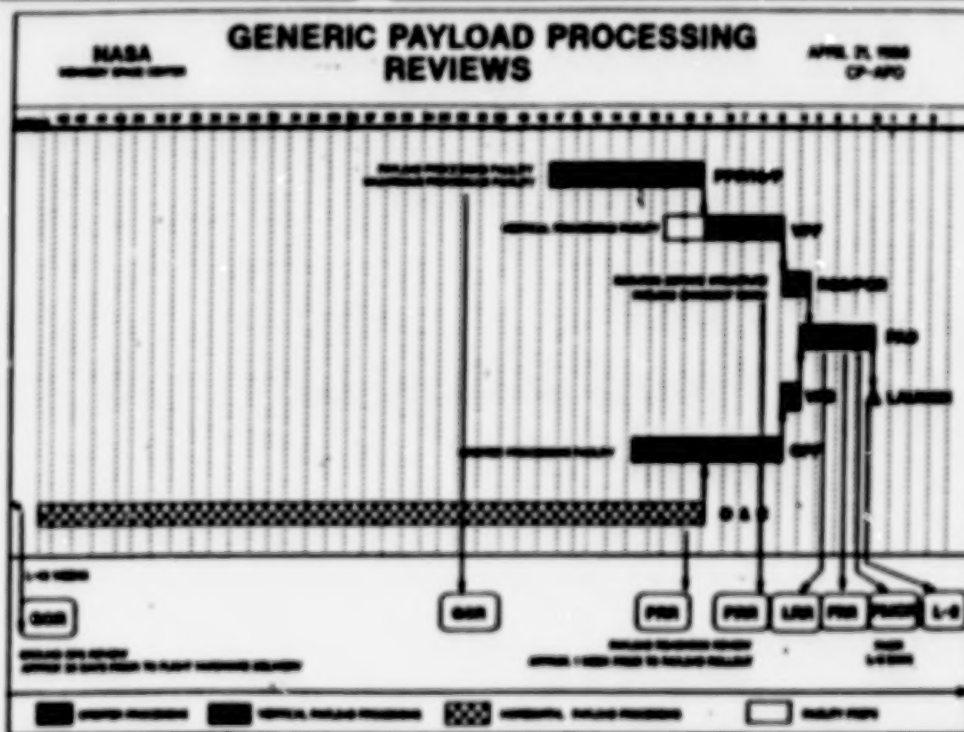
0 CUSTOMER SUPPORT REQUIRED DURING ALL PHASES OF INTEGRATION ACTIVITIES FOR GROUND OPERATIONS AND RELATED PAYLOAD TESTING.

0 REVIEWS REQUIRING CUSTOMER SUPPORT ARE:

- GROUND OPERATIONS REVIEW (GOR)
- PAYLOAD READINESS REVIEW (PRR)
- LAUNCH READINESS REVIEW (LRR)
- FLIGHT READINESS REVIEW (FRR)
- PAYLOAD MANAGEMENT COUNTDOWN REVIEW (PMCR)

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**SUMMARY OF AVAILABLE PFF'S**

**0 BUILDING AE**

- HIGH BAY WORK AREA: 43 FT. 10 IN. BY 51 FT. 6 IN.
- CRANE: 6-TON, 36 FT. 10 IN. LIFT
- CLEANLINESS: CLASS 10,000, CMV LEVEL 2
- ENTRY DOOR: 14 FT. 9 IN. WIDE BY 36 FT. 1 IN. HIGH

**0 HANGAR S**

- HIGH BAY WORK AREAS
  - o NORTH: 42 FT. 1 IN. BY 29 FT. 11 IN.
  - o SOUTH: 45 FT. BY 55 FT.
- CRANES: 2-TON, 19 FT. 1 IN. LIFT
- CLEANLINESS: CLASS 100,000, CMV LEVEL 4  
(CAN MAINTAIN CLASS 10,000, CMV LEVEL 2)
- ENTRY DOOR: 14 FT. 9 IN. WIDE BY 19 FT. 8 IN. HIGH





## Report Documentation Page

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16. Abstract <p>The purpose of the OAST In-STEP 88 Workshop was to identify and prioritize technologies that are critical for future national space programs and require validation in the space environment, and review current NASA (In-Reach) and Industry/University (Out-Reach) experiments. A prioritized list of the critical technology needs was developed for the following 8 disciplines: Structures; Environmental Effects; Power Systems and Thermal Management; Fluid Management and Propulsion Systems; Automation and Robotics; Sensors and Information Systems; In-Space Systems; and Humans in Space.</p> <p>Part I is the Executive Summary and Experiment Description. The Executive Summary portion contains keynote addresses, strategic planning information, and the critical technology needs summaries for each theme. The Experiment Descriptions portion contains brief overviews of the objectives, technology needs and backgrounds, descriptions, and development schedules for current industry, university, and NASA space flight technology experiments.</p>					
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